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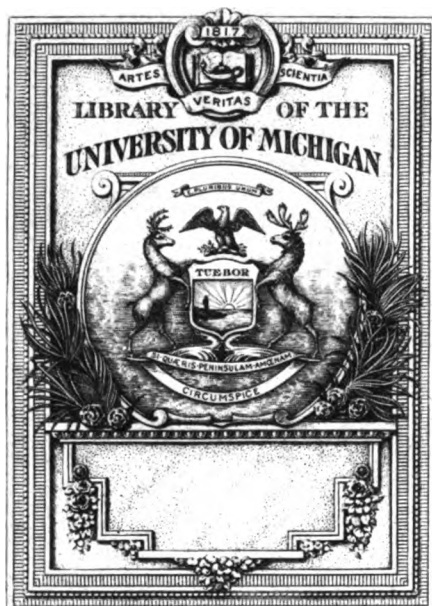
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UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
Missouri **AGRICULTURAL EXPERIMENT STATION**
RESEARCH BULLETIN 29

THE TARNISHED PLANT-BUG AND ITS INJURY TO NURSERY STOCK



COLUMBIA, MISSOURI
JULY, 1918

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Rich
Missouri

THE TARNISHED PLANT-BUG AND ITS INJURY TO NURSERY STOCK

(*Lygus pratensis* Linneus)

Leonard Haseman

The injury to nursery stock commonly known as "stop-back" or "bush-head" has been attracting the attention of nurserymen of the state for years. In some sections the injury seems to be increasing. It costs nurserymen, in labor and cull trees, thousands of dollars annually. While this injury is often very great in Missouri it is probably not as severe as in some other states.

There have been a number of views regarding the cause of this injury. Some have described it as the work of a small mite; others have considered it the work of thrips. Nurserymen generally have attributed it to faulty soil, stable manure, moist draws and to various other factors since its location in the nursery may often help lead to such conclusions.

For many years the tarnished plant-bug has been known to do similar injury by feeding on various herbaceous plants. In 1895 Slingerland^{1*} first attributed this bud injury on nursery stock to the work of the same insect. Since then various other workers including Lintner², Stedman³, Webster and Mally⁴, Felt⁵, Smith⁷, Lind⁸, Back and Price¹⁰, Crosby and Leonard¹² and others, have come to the same conclusion.

One visit to a block of nursery stock in 1912, when the injury was in progress, was sufficient to convince the writer that in Missouri the tarnished plant-bug, with its piercing mouth parts, is responsible for this wholesale injury. The peach twig-borer occasionally destroys the buds of peach and causes similar injury, and in one case a mite was found in a decaying bud; but the injury from all other possible sources is negligible when compared with the work of the tarnished plant-bug. The writer has seen blocks of peach, cherry and pear fairly swarming with the actively feeding tarnished plant-bugs, just at the time of the severest bud injury. He has also

*Superior numbers refer to literature cited on page 21. For a complete list of the literature on the tarnished plant-bug and its work the reader is referred to Cornell University Agricultural Experiment Station Bulletin 346, page 500.

obtained the typical bud injury to peach in the insectary by introducing tarnished plant-bugs into breeding cages with small peach trees. The nurserymen of this state who have trouble with "stop-back" must look to the control of the tarnished plant-bug as the one means of relief.

HISTORY OF THE PEST

The pest was first described in 1746 by Linnaeus in Sweden under the name of *Comex grisens*. Later the specific name was given as *pratensis*, meaning "found in meadows." In this country Say first described the species in 1831. Various other workers in different countries have redescribed it under at least sixteen different names and its generic name has also been changed several times, but it is now known as *Lygus pratensis* Linnaeus.

Geographically the species is widely distributed over the world and it has a wide range of food plants. The records of its injury to plants are even more numerous and variable than the descriptions and names given to the species. It has been repeatedly found injuring fruit trees, including apple, pear, peach, plum, cherry, quince and apricot. It has also injured strawberry, currant, gooseberry, grape, blackberry and raspberry. Among the truck crops, potato, cabbage, turnip, celery, beets, and beans have probably suffered most. Practically all flowering plants such as chrysanthemum, carnation, peony, aster, dahlia and zinnia are attacked, often very severely. Some of the flowering shrubs and even field crops such as wheat, corn and oats have been reported severely injured by the pest.

HIBERNATION AND EARLY SPRING WORK

Hibernation.—In Missouri the tarnished plant-bug seems to winter entirely in the adult stage. The writer has thus far been unable to find it wintering in any other stage. For wintering it selects sheltered places which are not too damp. It is found most abundantly between the leaves of various plants, especially mullein. Occasionally it may be found in rock piles, wood piles, under lumber, under bark of trees, among leaves and rubbish and in other more or less sheltered places. Judging from numerous observations the pest does not winter as successfully as many insects. Collections of bugs from mullein plants February 13 and 17, 1916, showed as many as fifty per cent dead in some cases.

The pest continues to breed and feed until after the first frosts in the fall. Adults and nymphs in different stages of development have been swept from matted specimens of their favorite food plant, *Erigeron canadensis*, (See Fig. 1) as late as the first of December, long after most weeds had been killed by frost. They seem to have more vigor than most insects. Specimens taken from mullen plants in mid-winter, when the temperature is below freezing, are able to move about and when warmed slightly are almost as active as in the summer, altho they show no tendency to fly until completely warmed.

Early spring work.—The tarnished plant-bug is destructive to various crops thruout the entire summer; but in the nursery (this report will consider it merely as a nursery pest) it is usually injurious for only a few weeks in the spring. The severest injury to nursery stock is done between April 20 and the last of May, altho it may continue to do some damage until the first of July. The damage which the nurseryman dreads is due to the work of the bugs which pass the winter. The hibernating adults begin to leave their winter quarters as soon as the sap begins to flow in plants. They may feed by extracting sap from various early plants before they appear in the nursery. Some seasons they may begin to feed in the nursery just as the dormant buds begin to open. Then, sometimes they may appear after the trees are out in leaf and the new growth is a few inches long. Again they may not attract attention until the new growth is from eighteen inches to two feet long. The date of appearance in the nursery may vary greatly from year to year without any apparent cause. In 1915 the tarnished plant-bugs were found on wing in Southeast Missouri March 18, and in Central Missouri their work on nursery stock began to show by April 20 and the pest was in greatest abundance about April 27. The nights were yet cool but in midday, summer temperatures prevailed. The injury continued until heavy rains in early May helped to put a stop to their work.

One year they may seem to prefer pear, while the next year they may attack cherry, peach, or possibly the peach seedlings most severely. The proximity of the particular block of stock to woods, fence rows and other places which will furnish winter shelter for the bugs undoubtedly helps to explain this seeming preference for one variety one year and another the next. The first signs of damage invariably show in those blocks which are next to the best winter shelter and are also exposed to the spring sun.

LIFE HISTORY

Until recently the complete life cycle of this species has been unknown. Some related species have been carefully studied but most of the earlier records and some of the more recent ones, dealing with the life cycle of this species, have been decidedly incomplete and inaccurate. Howard⁶ states that there are probably five instead of four molts and Chittenden and Marsh⁸ state that there is little doubt that there are five stages, but the writer's brief report in 1912¹¹ seems to give the only records that have yet been obtained from actual breeding experiments. The only way that one can be sure of his ground in work of this nature is actually to rear the insect from the egg to the adult stage. With this species at least, one can not distinguish with certainty the first three nymphal stages by simply collecting the nymphs at random and grading them by size. One must rear them from the egg and follow their development hour by hour and day by day.

Oviposition.—The writer's observations on the egg-laying habits of the pest have been confined largely to the summer and fall seasons. On June 5, 1912, just after the pest had completed its injury to a block of peach in Central Missouri, the writer found it fairly swarming over an adjoining field of red clover which was in full bloom. It was probably ovipositing in the clover blossoms, altho at that time no observations were made to determine this. The writer has failed to observe the pest ovipositing in the soft tissues of nursery stock or other plants, altho Crosby and Leonard¹² and Crittenden and Marsh⁸ report cases where the pest has been observed to deposit eggs in such tissues. If eggs are deposited in such places, it seems unusual, judging from the writer's observations, and oviposition in such places is certainly of no importance either in connection with the question of injury to nursery stock or methods of control. The injury to nursery stock is due to the feeding of the adults, and nymphs have not been found by the writer on nursery stock.*

The normal place for depositing eggs during the summer and fall is in the blossoms of various plants, more especially composites. (See Fig. 2a.) The insect shows a preference for the common weed, known as "mule's tail" or "mare's tail", *Erigeron canadensis*, and strange to say, the nymphs and adults show a marked degree of

*During the first week of June, 1918, the writer found the pest breeding on horse-weed and smart weed in a block of peach seedlings at Columbia, but failed to find eggs in the soft tissues of any of the plants, and the pest did not attack the seedlings.

protective coloration and shape when on the plant, while the eggs may readily be mistaken for the developing, plump, oval seeds. (See Fig. 2b.) The writer has repeatedly been impressed by the fact that a careful examination of one of the plants may reveal the presence of from none to possibly two or three nymphs, when later a careful brushing of the plant may show that it contains a dozen or two nymphs in different stages of development.

The adult on preparing to oviposit rests on the blossom, and by means of her ovipositor, places the egg down between the flowerlets, and cements it to the side of a flowerlet as shown in the illustrations. The eggs are placed down in the flower endwise so that on hatching the nymph simply pushes its way out to the surface. Usually partly matured blossoms are used and the eggs hatch before the seeds mature and drop out.

The Egg.—The freshly laid egg has the color of clear protoplasm. Later it takes on a yellowish color and the pigment of the eyes and the dorsal gland show thru the egg shell. The egg is oval, slightly curved, somewhat enlarged toward the base, and near the tip is a ring-like thickening or constriction beyond which is a short plug-like portion similar to eggs of other related *Hemiptera*. (See Fig. 3a.) The eggs vary in size but average about 1 millimeter in length and 0.27 millimeter in greatest diameter. The size and shape of the egg agree remarkably well with those of the developing seed of *Erigeron canadensis* and when placed in the blossom among the seeds of this plant it may readily be mistaken for the seeds. However, the egg shell has a polished surface and when viewed with the right light shows beautiful sculpturing.

Usually but one egg is found in a blossom, altho occasionally as many as three have been found in the same blossom. The time required for the egg to hatch seems to vary somewhat but averages about seven to ten days. Freshly laid eggs observed on September 18 developed eye spots on September 23 and hatched September 27.

The nymph.—The tarnished plant-bug passes thru five nymphal stages in developing. Wings appear with the fifth molt. The first three nymphal stages have always been confused. After days of constant observation on the molting and development of the pest, the writer succeeded in isolating the first three nymphal stages. The fourth and fifth nymphal stages are readily distinguished.

First nymphal stage.—The young nymph is yellowish in color with a greenish cast posteriorly. The pigment of the dorsal gland is bright orange. The antennae are sooty-gray, annulate with white;

the fourth segment is sooty at the base, and grades thru lemon to orange at the tip. The eyes are bright red with a purplish cast. The beak is black at the tip, and lighter toward the base. The base of the tibia is marked with a dark red spot.

On hatching the nymph varies from 0.85 millimeter to 1.1 millimeters in length and from 0.36 millimeter to 0.45 millimeter in breadth. In from six to eight days, depending on temperature, the nymph is ready to molt. It is then about 1.3 millimeters long. In the first stage the lengths of the antennal segments, beginning with the basal segment, are 0.09, 0.23, 0.20 and 0.35 millimeter. (See Fig. 3b.)

Second nymphal stage.—In the second nymphal stage the color deepens, and green replaces yellow or yellowish-green. The body becomes relatively broader. The antennae becomes reddish, annulate with white. The dorsal gland is dark with an anterior orange blotch. The red spot at the base of the tibia becomes more conspicuous and a similar spot begins to appear just above on the femur. The legs turn brownish and the eyes are dark red. When the nymph molts and enters on the second stage it is about 1.3 millimeters in length. After feeding for from 4 to 6 days it becomes full-fed and ready to molt a second time. It is then about 1.6 millimeters long and 0.61 millimeter broad. The lengths of the antennal segments are 0.14, 0.36, 0.36, and 0.45 millimeter. (See Fig. 3c.)

Third nymphal stage.—In the third stage the nymph becomes more plump; however, the writer for a time mistook the third stage for the fully developed second stage. The color deepens and the red spots and bands become more conspicuous. The spot at the base of the tibia and the one near the tip of the femur are larger and form incomplete bands. The beginning of a second femoral band appears. The general color of the body above is green; but toward the close of the stage the four dark thoracic spots begin to appear. These become conspicuous in the following two nymphal stages. The hind margin of the mesothoracic and metathoracic segments become concave, altho distinct wing pads do not appear until the next stage.

The young third-stage nymph is about 1.7 millimeters long and after feeding for from 5 to 6 days it is ready to molt a third time. It is then about 2.1 millimeters long, 1 millimeter broad and the lengths of the antennal segments are 0.23, 0.55, 0.41 and 0.45 millimeter. (See Fig. 3d.)

Fourth nymphal stage.—In this stage the nymph begins to develop some real color patterns. Red, white and black predominate.

There is great variation in the extent of color possessed by different individuals. The males show more color than the females. Transverse red blotches appear on the abdominal segments and on the thorax. The four black thoracic spots become more prominent. The pigment surrounding the dorsal gland becomes bright red with a black center. A black spot appears on either side under the edge of the prothorax. The eyes become deeper purple. The antennae are dark red, annulate with white, and in pale specimens the central light band on the second segment is yet present. The proboscis is marked with red but is still tipped with a sooty patch; it reaches back to the sixth abdominal segment. The legs and ventral surface of the body become conspicuously blotched with red. The tips of the tarsi remain sooty. Near the tip of the tibia appears a red band; two similar bands appear near the base of the tibia; two toward the tip of the femur and a large blotch toward the base of the femur. The nymph really takes on gorgeous markings resembling the markings on the maturing seed clusters of *Erigeron canadensis*.

At the beginning of this stage the nymph is about 2.1 millimeters long, and after feeding for from 4 to 6 days (eight in one case) it becomes about 3 millimeters long, 1.5 millimeters broad and the lengths of the antennal segments are 0.27, 0.82, 0.64 and 0.60 millimeter. The wing pads extend to the third abdominal segment. (See Fig. 3e.)

Fifth nymphal stage.—In this stage the females are less brightly marked than the males and the ovipositor and sheath show thru the abdominal segments. The wing pads in the nearly mature fifth-stage nymph project back to the sixth abdominal segment. The veins begin to appear in the pads. The general coloring in the fourth nymphal stage becomes even more pronounced in the fifth stage. The banding and blotching on the wing pads, abdomen and legs become more conspicuous.

The young fifth-stage nymph is slightly over 3 millimeters long. In about five days it becomes full-fed and ready to molt for the last time. Before molting it is about 4 millimeters long, 2.1 millimeters broad and the lengths of the antennal segments are 0.41, 1.1, 0.82, and 0.73 millimeter. (See Fig. 3f.)

Adult stage.—In the transformation from the first nymphal stage to the adult insect, along with the enormous increase in size and the development of wings, may also be noted the peculiar change in the relative lengths of the antennal segments. This has also been noted in other insects. In the young first stage of the nymph, the

basal segment is shortest, the last segment longest and the second segment slightly longer than the third. In the third nymph stage the second segment becomes the longest but the last segment is only slightly shorter. By the time the fourth stage is reached, the length of the last segment has dropped to third place, and in the fifth nymphal stage, as well as in the adult stage, the basal segment is shortest, the second segment longest and the third slightly longer than the fourth or last.

In the adult stage part of the markings of the last nymphal stage are maintained. The males are much more deeply colored than the females. The more brightly marked males appear as if they had been painted, while the paler females appear as if the color had bleached out. Individuals of the same sex vary a great deal in coloration, altho not so much as individuals of opposite sex. On first maturing, the adults are pale but in one or two days the markings deepen.

Typical males collected in September have a ground color of purplish-brown grading to black below. This ground color is striped and blotched with white, yellowish-white, reddish-brown and black. The antennae vary from dark brown to black, faintly annulate with white. The proboscis is tipped with black, and becomes paler toward the base with two distinct longitudinal dark stripes on the two basal segments. The upper lip and stilets are brown. The head is blotched with black, brown and yellow. The eyes are purplish-black. The legs are marked and banded as in the last nymphal stage. The tarsus is sooty at the tip, and brownish toward the base. The tibia has a dark, reddish-brown blotch at the tip and two similar ones near the base. The rest of the tibia is straw colored. The tibia is armed with short but strong spines. These are arranged in four longitudinal rows and a group surrounding the tip. The femur has two of the dark colored bands near its tip and a much broader one covering most of the basal half of the segment. The trochanter and tip of coxa are lighter while the base of the coxa is dark.

The lower surface of the thorax and abdomen is all of the brown, dark brown, or black shades except for lighter markings as hereafter described. The seven abdominal and two thoracic spiracles are surrounded by white or yellowish patches which grade thru reddish to the dark ground color. Beginning on the seventh abdominal segment and extending forward to the thorax are two medio-lateral yellowish bands. These are crossed by reddish stripes at the sutures, and with a dark stripe on the second segment. On the

thorax these light stripes can be traced as two interrupted narrow bands; the lateral one runs along the edge of the prothorax while the inner one includes the light areas around the two thoracic spiracles. On the hinder margin of the prothorax is a narrow, whitish band which is continuous above.

On the dorsal surface the most deeply colored males are almost black with white, yellowish or brownish lines and blotches. On the pronotum are five more or less distinct longitudinal yellowish-brown blotches. The scutellum is yellowish-white, the very tip creamy-white, with a central and two lateral dark stripes which unite with the dark basal portion. The membrane of the front wing is sooty, the veins white. The cuneus is sooty with whitish margin and is tipped with black. The caustal margin of the wing is yellowish-white. The basal wing veins are light and on the clavus is a very distinct white line which is interrupted for a short distance just before it reaches the membrane. (See Fig. 3g.)

In the less highly colored males black is replaced by purplish-brown, brown, or copper and the light markings are even lighter than those in the foregoing description. The females are still lighter. Their color is coppery or brown. The dark markings may be almost completely lost, but where they are preserved they are brownish. Around the base of the ovipositor is usually a dark brown patch which may extend to the thorax. (See Fig. 4.) The lateral dark areas are restricted to brown or dark brown blotches on each segment just ventral to the spiracle. Between the base of the first and second pair of legs is a yellowish-brown spot which also appears brownish in the light colored males.

The female is 5.9 millimeters long and 2.4 millimeters broad. The body of the male is scarcely as broad as that of the female. The wings of the males project more so that the males appear to be nearly the same size as the females. The lengths of the antennal segments are 0.55, 1.6, 1.1, 0.82 millimeter. The last segment of the antennae of the male is slightly longer than that of the female.

INJURY TO NURSERY STOCK

The damage by the tarnished plant-bug to vegetables, flowers and small fruits is often very great, but in Missouri the pest attracts most attention in the nursery. The greatest damage occurs early, as a result of the feeding of the adults which passed the winter, altho in some seasons the pest may continue to do considerable

damage until midsummer. The opening buds and growing tips of twigs on nursery stock seem to attract the adult bugs in the spring. They usually come from winter quarters before the fruit tree buds open and may be found feeding on various early spring plants for some time before the injury to nursery stock begins to appear.

The "sting" of this bug seems to be unusually injurious to the buds of fruit trees. On the other hand it seems to do but slight injury to the common weed, *Erigeron canadensis*, on which it feeds and breeds abundantly thruout summer and fall. The injury to fruit buds may be due in part to the loss of sap, but the blighting effect of glandular secretions which are introduced into the wound along with the stilets probably accounts for most of the injury. (See Fig. 5.) Little is known about the glands and the chemical composition of the secretions associated with the feeding apparatus of the *Hemiptera*, altho the blighting or irritating effects of these secretions on plant and animal tissues are well recognized. The writer has succeeded in getting the typical bud injury on peach by hypodermic injections of extracts from the heads of tarnished plant-bugs.¹

When the tarnished plant-bug attacks a peach bud, the bud soon wilts, turns dark and later the bud drops out, leaving a slight pit and usually a small amount of wax. (See Fig. 6c.) This forces side buds, which produce a low bushy tree, if any at all.

In some seasons this pest may completely destroy the buds before they have scarcely opened. In other seasons they may appear in the nursery later when they produce the characteristic "bush-head" or "stop-back" condition. (See Fig. 6a, b.) In still other seasons they may cause no appreciable damage. During a given season, peach buds may be attacked. During another season pear, cherry or perhaps the seedlings of these fruits may be attacked. Peach and pear usually are damaged most but apparently the proximity of the block to the winter quarters of the bugs determines which block of trees will suffer most. (See Fig. 7a, b.) Tarnished plant-bugs do not multiply on nursery stock, so that growing nursery stock year after year in the same field or adjoining fields does not result in an increase of the pest. On the contrary some of the greatest damage has resulted where nursery stock was grown for the first time miles away from other nurseries. This was well illustrated by a block of peaches, grown years ago by one of the nurseries in Central Missouri, miles

¹An investigation of the salivary glands and secretions of the pest is under way by the writer.

from other nurseries. The relative abundance of plants on which the pest breeds in any locality during the summer, together with climatic conditions during the fall, winter, and spring, largely determine how abundant the pest will be in the spring and how great will be the damage to nursery stock.

REMEDIAL MEASURES

Most workers are inclined to consider the tarnished plant-bug and its injury to nursery stock entirely beyond the reach of man. Perhaps this is true, but, some of the results obtained in connection with this investigation may be worth noting. With a clear understanding of the nature of the pest, its breeding habits and its work on the nursery stock, it can be readily seen why most of the direct treatments, notably the application of spray solutions, can give little or no results. Preventive measures prove more effective.

Clean culture.—While the tarnished plant-bug has a wide range of food plants, it seems to do most of its breeding on but a few species of plants. These probably vary in different sections of the country, but in Missouri it seems to breed mostly on the fleabane, *Erigeron canadensis*, different species of daisies, golden rod, wild asters, and similar plants. It does not seem to breed on trees, strawberry, vegetables or other cultivated crops which it may damage seriously. It may seem queer that the plants which it damages most are not the ones on which it breeds, but the observations reported herein show this to be true.

The practice of clean culture, therefore, becomes one of vital importance in a campaign to reduce the number of tarnished plant-bugs and their injury to nursery stock. The pest breeds not on cultivated crops but on certain weeds, the systematic destruction of which is an essential part of good agricultural practices.

The destruction of weeds and other plants on which the pest breeds, especially during the latter part of the summer and early fall, is necessary if the number of bugs, which will injure the nursery stock the next spring, is to be reduced. The nursery should be thoroly cultivated to keep down all kinds of weeds, and fence rows, gullies and adjoining fields should be mowed once or twice during the summer and fall. (See Fig. 8.) Hundreds of the bugs may mature on a single weed so that it is necessary that the work be thoroly done. In some cases the nursery adjoins farm land but it is usually possible to induce the farmer to assist by keeping down weeds. In case

he is unwilling to do so the nurseryman can well afford to keep down the weeds for him.

It is true that the tarnished plant-bug is a strong flier and may migrate considerable distances but most of the bugs found in the nursery in the spring are bugs which matured and passed the winter in the immediate vicinity of the nursery. To test the effect of clean culture in and around the nursery, isolated plots in one of the nurseries of Central Missouri have been used. No attempts have been made to enter neighboring farms to keep down weeds but special efforts have been made to destroy "mare's tail" and other weeds in the nursery, along fence rows and on ground surrounding the nursery. This has invariably resulted in a decided reduction in the amount of injury to the nursery stock the following spring. Injury has not been entirely prevented but the results have been so decided that in this nursery the systematic destruction of weeds is considered essential as a means of preventive damage from the tarnished plant-bug.

Destruction of hibernating places.—The adult tarnished plant-bugs hibernate in various protected places, and they fly from these in the spring to the nursery. Mullen plants perhaps furnish the best winter protection for the pests in Missouri but, while it is difficult to find them, undoubtedly many seek shelter under rocks, leaves and other rubbish in woods, along fence rows and similar neglected places. In the nursery the heaviest attack and the first injury appear in those nursery blocks next to woods or other favorable winter quarters. Isolated blocks may show almost no signs of injury while other blocks, near favorable hibernating places, may be literally riddled. A block of coming two-year pear and cherry, grown along a weedy country road, and a block of coming one-year pear, grown along a wood, in the same nursery in 1915 clearly showed the effect of favorable hibernating places near blocks of nursery stock. These blocks were severely damaged. The young pear trees were almost completely destroyed, while blocks of peach and peach seedlings better isolated from favorable hibernating quarters were only slightly injured. Even this slight injury occurred later after the bugs became more widely scattered.

The varied nature of the places selected by the pest for hibernating and the extent of ground to be covered make it difficult to fight the pest economically by treating its winter quarters. Road sides and fence rows overgrown with weeds and briers, leaf-matted, wooded slopes and rocky hillsides with abundant supply of mullen

plants are some of the pest's most favorable winter quarters and all such places can be profitably treated. Observations on the effect of cleaning out fence rows and ditches and fall plowing of fields adjoining the nursery have shown that treating hibernating places is of value in the prevention of injury to nursery stock.

Trap crops.—Early in this investigation it was observed that the injury was not always evenly distributed over the nursery blocks. Along the ends and edges next to pastures, clover fields and other crops, there was often a noticeable absence of injury, while the bugs were present in the adjoining crop in large numbers. This lead to the supposition that part of the bugs were attracted from the trees to the adjoining crop. Where clean culture is practiced there is practically nothing green in the nursery blocks except the trees which must furnish all the food for those bugs out some distance in the nursery. If the absence of other green plants in the nursery makes it necessary for the pest to feed entirely on the nursery stock then it seems entirely possible that some crop might be grown in the nursery to help feed the pest. In Missouri the pest leaves winter quarters early, often before growth starts, so that if a crop is to be used it must be one which starts early or which carries green foliage thru winter. The crop must also be attractive to the pest and must be one which can be sown after the last cultivation in fall. Of the various possible crops, wheat and rye seem most desirable and the tarnished plant-bugs have been found in great numbers in wheat early in the spring.

During the fall of 1913 wheat was sown between the rows of trees in some of the experimental nursery blocks. The following spring the bugs were abundant but later observations showed that they did less injury than usual to the stock early in the season. The results of this first test were so encouraging that the nurserymen decided to sow wheat or rye in all of the blocks of stock the following fall. Rye was suggested as a substitute for wheat to avoid the danger of providing breeding places for the Hessian fly by sowing wheat early in the fall. Wheat and rye sown in September make a very heavy growth before winter, and usually during early March growth is resumed. Unfortunately early cultivation of the nursery destroys most of the crop before the season for the heaviest bud injury arrives.

The second year's experience proved conclusively that this type of trap crop can not be successfully used in the nursery, since it is destroyed before the time at which it is most needed. The following

is a quotation from the nurseryman's letter of April 16, 1915. "We have found a few of these bugs in wheat adjoining the peach but have not yet found any of them actually on the peach." He wrote again April 19. "To us it seems the opportune time to see the tarnished plant-bug doing its best or rather its worst on the pear buds and he is also in evidence on the peach. On some of the seedling pear stocks, where the buds did not set, but were left standing, you will find as many as eight to ten tarnished plant-bugs on a single seeding. The wheat that we sowed, and is only partially destroyed (by cultivation) has apparently been no check whatsoever, so that we have lost some faith in this theory of ours about giving them something else to eat."

The writer visited the nursery the following week, April 27, and found the bugs present by the thousands in the pear and cherry blocks, and in places the stock looked as if it had been scorched by a fire. At this time the trap crops had been entirely destroyed by cultivation and the bugs were feeding on the nursery stock. Comparatively little injury had appeared on the peach trees and peach seedlings, and later on in the season but little further injury was done.

While the second year's work with the use of a trap crop between the rows of trees failed to give particular value, the use of a trap crop will not be given up in the nursery. Experience has shown that the pest can be attracted to certain crops early in the spring and it is simply necessary to arrange a system for maintaining an attractive crop alongside the nursery blocks thruout the season of severe injury. To do this the nursery blocks may be reduced in size and field crops grown between. Clover, wheat, rye, grasses and similar crops which start growth early in the spring may be used. This method of providing a trap crop has been in use for the last few years in this nursery and besides providing a trap crop thru the season of severe injury, it also enables the nurseryman to utilize more of his land. It also enables him to keep down weeds and other plants which serve as breeding places for the pest.

Control by driving.—Driving will help to check the injury to nursery stock. It has been repeatedly observed that by cultivating thoroly or by spraying with Bordeaux mixture, just when the bugs begin to cause heaviest injury, the damage may be greatly relieved for a time. The work has somewhat the effect of driving. In the middle of the day the pest is easily driven from the trees, and with a strong breeze across the rows or at an angle to the rows, it is easy

to drive the pest off to one side of the nursery. This was tested in a small way by the writer and one of the nurserymen on April 27, 1915. The bugs were sluggish in the early part of the day, so that they could easily be caught by hand; but toward noon they became very active. A gentle breeze was blowing and by walking along the rows it was observed that practically all of the bugs on leaving the trees flew with the breeze and usually passed over two or three rows before alighting again.

It was planned to test the driving method on a large scale in a block of pear trees the next week, but heavy rains came in the meantime and so reduced the number of bugs that driving was considered unnecessary. A heavy, dashing rain has somewhat the same effect as a systematic drive, for nursery stock, especially the young stock, does not offer the tarnished plant-bug much shelter from dashing rains. The effect of a heavy rain in reducing the number of bugs in a block of nursery stock and the consequent reduced injury has been repeatedly observed by nurserymen. If a dashing rain comes soon after the bugs begin their work, the nurserymen usually find that "stop-back" troubles are largely checked. Of the different treatments which can be applied during the season of attack, driving is one of the most practical and effective.

Sticky shields.—Sticky shields used for destroying tarnished plant-bugs are not the small shields which can be carried by hand along the row. The ridiculousness of attempting to destroy the pest with such shields is at once apparent to one familiar with this insect and its great activity. On cool days and early in the morning it is less active to be sure but it cannot be approached and induced to fly against a small shield carried along the rows.

In order really to accomplish anything of value with sticky shields they must be built on a much larger scale, forming a sort of trap for surrounding the bugs and inducing large numbers of them to fly against the sticky surface.

A machine of this nature has been used for several years in one of the large nurseries of the state for controlling the apple leaf-hopper. The writer has had a good opportunity to determine its value as a means of catching both the leaf-hopper and the tarnished plant-bug. In recent years the tarnished plant-bug has not done a great deal of injury in this particular nursery, so that the machine with the sticky shields has not been used early in the spring to catch tarnished plant-bugs which winter over. However, when used later in the spring for catching the leaf-hoppers, it also catches great num-

bers of the tarnished plant-bugs. In the spring when the nursery stock is smaller and the foliage less abundant as shelter, the machine should be even more effective.

A machine of this type can be easily constructed at home. (See Fig. 9.) For the tarnished plant-bug the body of the machine need not be built so high off the ground as where it is used on scion orchards and large apple stock for catching the apple leaf-hopper. To prepare such a machine use two drill wheels or strong cart wheels and mount these on an axle which will clear trees at least four feet high. Make the frame work strong enough to carry two strong painted canvas shields which should be five feet high and ten or twelve feet long. The shields should be mounted so that they come within a foot of the ground and so that they extend slightly beyond the head of the horse or mule used to pull the machine. Two rows of trees should be covered, and the horse or mule working in shafts, serves as an agitator. For early spring painted canvas should also cover most of the top of the machine and canvas or gunny sacks should close the machine behind. The paint for the canvas may be prepared at home. Five pounds of rosin boiled in one-half gallon of castor oil and applied to the canvas while hot makes a good paint.

When the bugs begin to attack the stock in the spring, the machine should be run every day. It will cost about three dollars a day to run such a machine and one machine will cover from twenty to thirty acres a day.

Insecticides.—Of the various possible remedial methods, the use of insecticides has proved most discouraging. The injury is done by the adult winged insect and the contact sprays used ordinarily for the soft bodied lice and other types of sucking insects have been entirely ineffective. Sprays which are sufficiently strong to kill the pest outright can not be safely used on nursery stock. The great activity of the pest, except when the weather is cool, helps to reduce the effectiveness of sprays. Sprays and dusts used as repellants also have proved valueless except in that they have served as a means of driving the bugs from the nursery block at a time when they are doing the most damage. So far as present knowledge of insecticides is concerned the only possible way in which they can be used with any degree of success against this pest is to make use of them in connection with driving. For this purpose their use is too expensive in view of simpler methods of driving which are more effective. From the beginning the writer has ignored their use as a

remedy against this pest in the nursery, altho some spraying work has been done by nurserymen themselves, who used Bordeaux and arsenate of lead as repellants. The results secured by other workers where insecticides have been used, show that present day insecticides have no place in a campaign against this pest in the nursery.

Pruning.—Pruning is to be considered simply as a means of overcoming the damage after it has been done. Where the attack does not come too early in the spring careful pruning will usually largely overcome the damage, but where the pest begins its work early, almost before the buds have started, pruning is of little avail. If pruning is to give any appreciable results it must be done by experienced men which will involve much additional expense, so that it should be relied on, therefore, only as a last resort. It is better to prevent the injury if possible.

Selecting a site for a nursery.—In the selection of a field for growing nursery stock, the soil, accessibility, and other important factors must first be considered. Other conditions being equal, select a site as remote as possible from places in which the pest may hibernate and from field and waste places where various weeds on which the pest breeds may grow. The tarnished plant-bug is not a pest which has been developed by growing nursery stock continuously, in any locality. It is a pest which in recent years has been turning from weeds and other plants on which it breeds to nursery stock, especially in the spring when that stock proves attractive as a food plant. So far as this pest is concerned, the proximity of the new nursery site to crops of weeds and to favorable winter shelter is more important, therefore, than its proximity to older nursery blocks.

CONCLUSIONS

1. The typical injury to nursery stock, known as "stop-back," "bush-head" or "bunch-head" in Missouri is the result of feeding by the tarnished plant-bug. This injury has been common in the state for years but has attracted special attention only in the last seven years.

2. The main injury is done by the adults which pass the winter. Some of the late work may be done by adults maturing in the summer. The nymphs do not breed and feed on nursery stock.

3. The principal injury is done in the spring before the dormant buds have produced a growth of more than twelve inches. Later injury does occur but it is usually of little importance.

4. Peach, pear and cherry are most severely attacked in Missouri.

5. The pest hibernates in the adult stage between the leaves of mullein and similar plants, under rubbish, leaves and other shelter. Only a small per cent of the adults which hibernate live thru the winter.

6. The bugs are strong fliers but collect in greatest abundance and do most damage on nursery stock near favorable breeding and hibernating places.

7. In the development of the pest it passes thru five nymphal stages, the second of which can not be distinguished with certainty without actually following the hourly growth and development of the nymph from the time it hatches.

8. The pest oviposits largely in the blossoms of composites and the nymphs feed on the sap of the same plants. "Mare's-tail," *Eriogon canadensis*, is preferred, altho the pest breeds on a variety of other plants.

9. In the control of the pest clean culture to destroy plants on which it breeds and the destruction of favorable hibernating quarters are essential. Trap crops, sticky shields and driving will also help to reduce the amount of injury. Known insecticides are of little or no value. Judicious pruning will help reshape injured trees.

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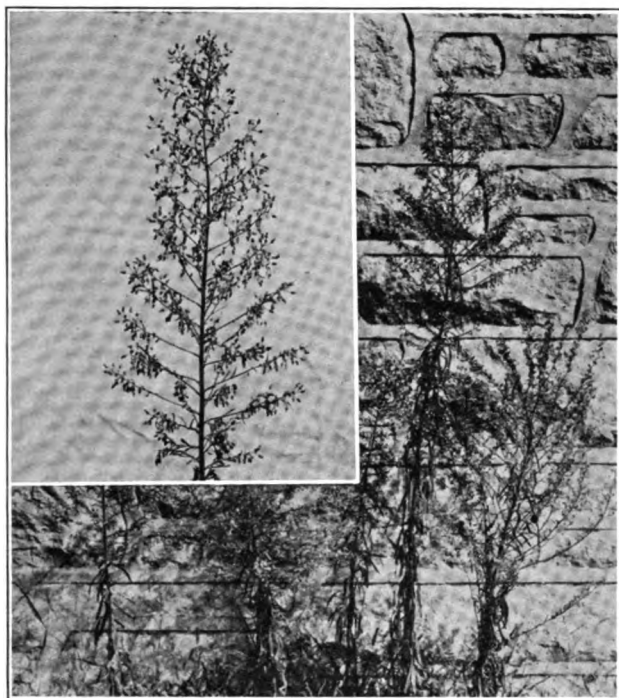


Fig. 1.—“Mares-tail” (*Erigeron canadensis*), the plant used most by the tarnished plant-bug for breeding

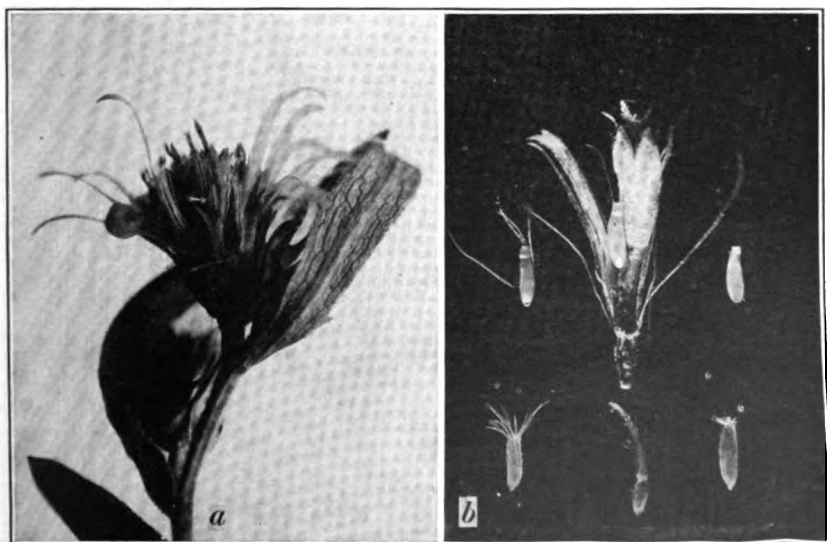


Fig. 2.—Tarnished plant-bug egg: *a*, In blossom of wild aster; *b*, showing attachment of egg and its resemblance to immature seeds of *Erigeron canadensis*

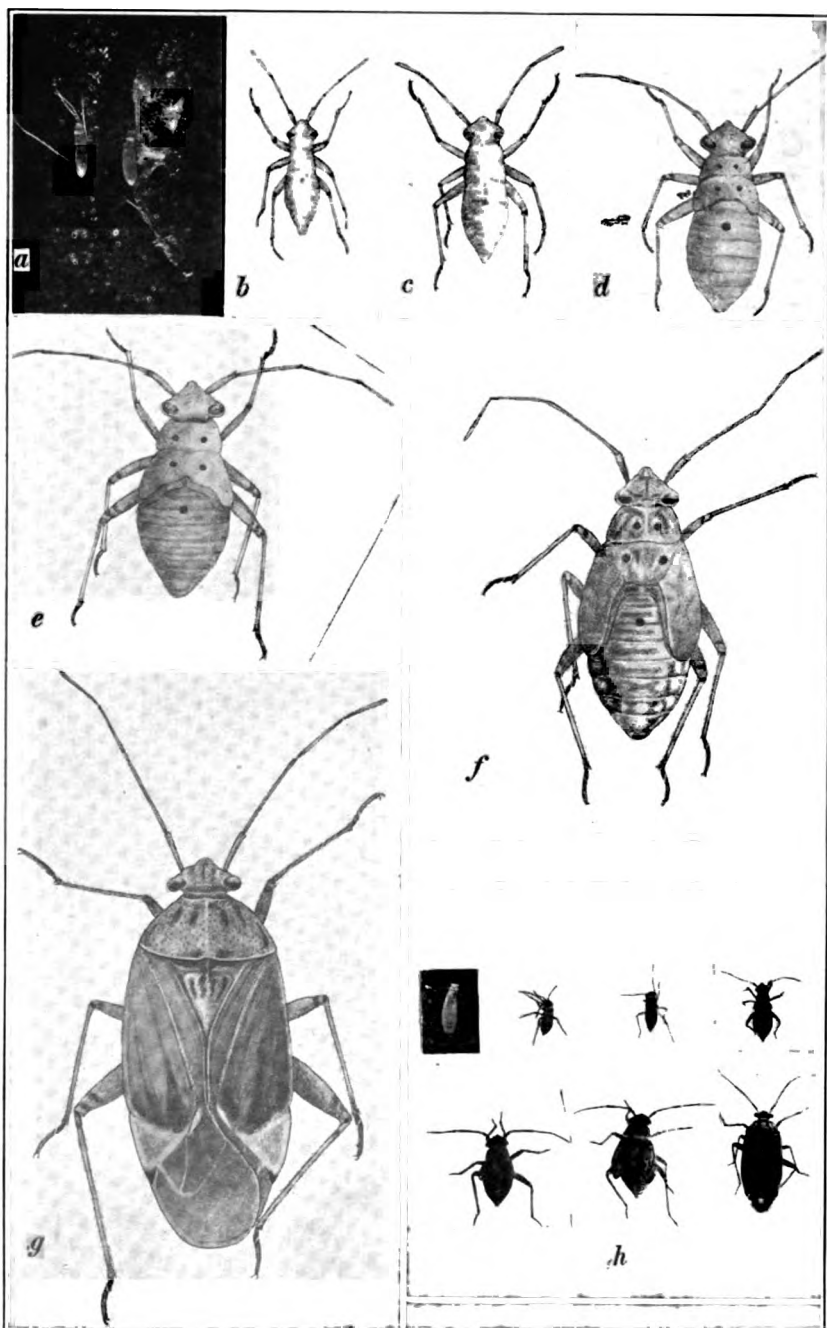


Fig. 3.—Tarnished plant bug: *a*, Egg; *b*, first-stage nymph; *c*, second-stage nymph; *d*, third-stage nymph; *e*, fourth-stage nymph; *f*, fifth-stage nymph; *g*, adult; *h*, photographs showing same



Fig. 4.—Tarnished plant-bug: Female, ventral view of abdomen showing ovipositor partly removed from sheath

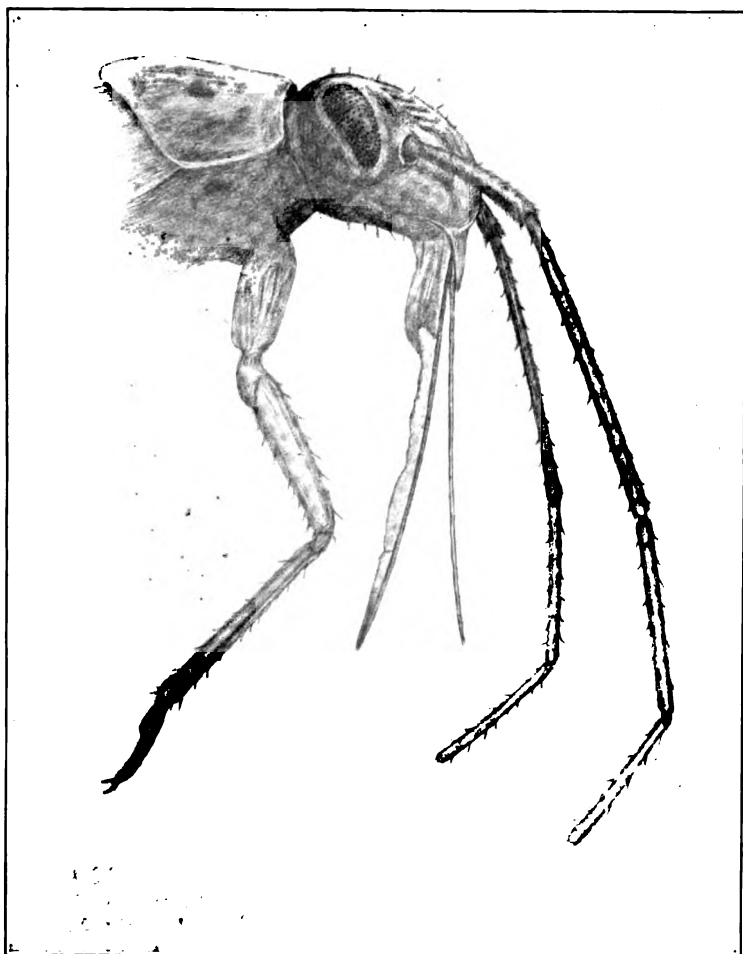


Fig. 5.—Head of tarnished plant-bug showing sucking beak and its attachment to head

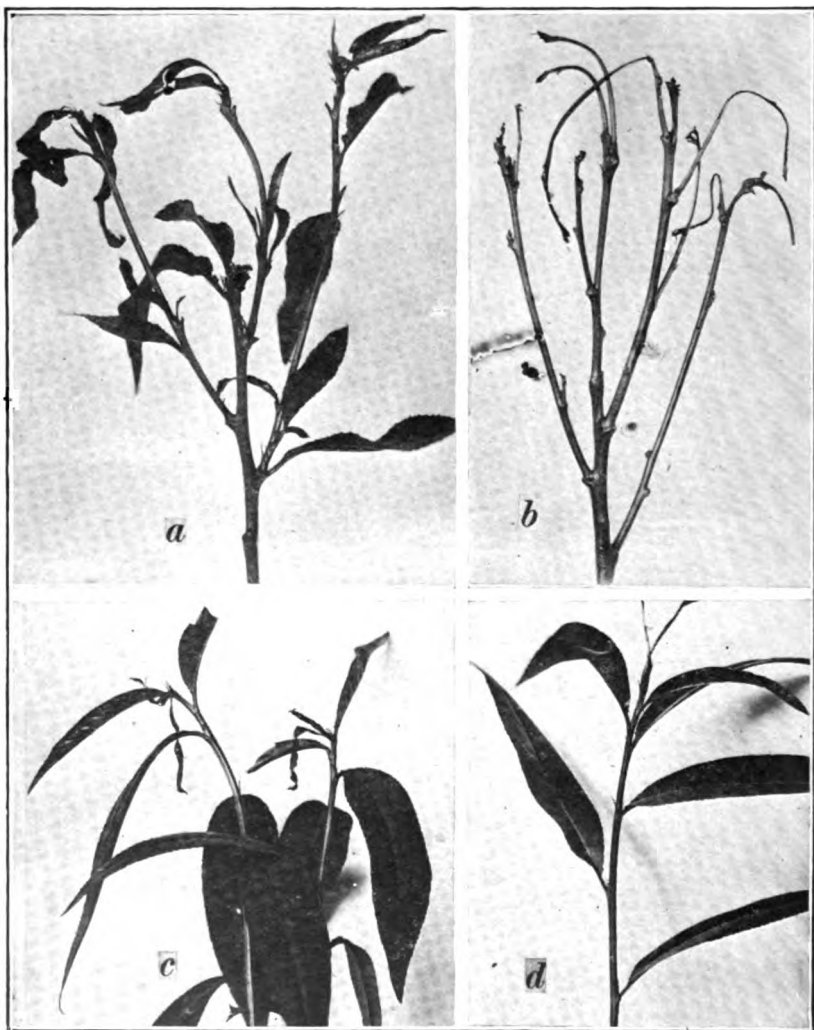


Fig. 6.—Tarnished plant-bug work on peach: *a*, Injured tree; *b*, injured tree with leaves removed; *c*, peach buds showing fresh injury; *d*, healthy peach bud



Fig. 7.—Nursery stock: *a*, block of peach buds at stage when most of bud injury is done; *b*, individual tree with severe bud injury

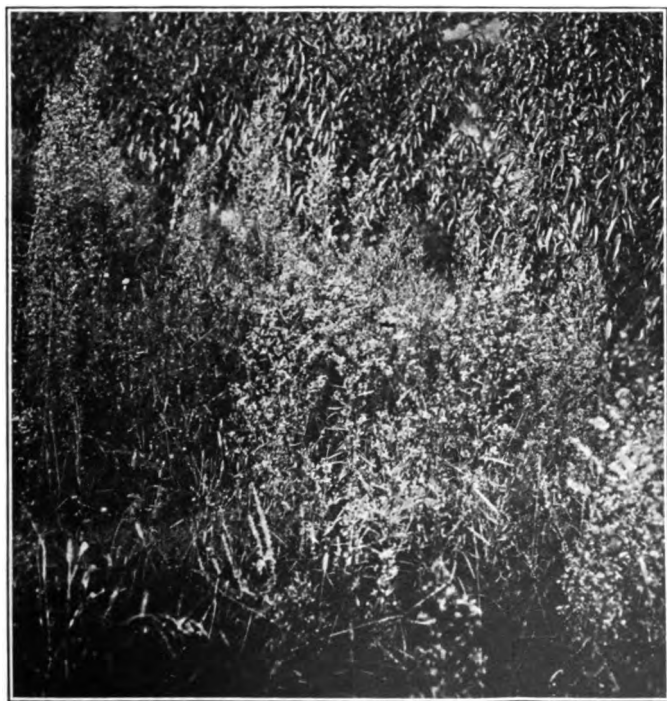


Fig. 8.—Neglected fields, with crop of "Mares-tail" on which the tarnished plant-bug breeds



Fig. 9.—Bug exterminator, showing sticky shield used in one Missouri nursery for catching the hopping and flying insect pests of nursery stock

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
RESEARCH BULLETIN 30

COMPOSITION OF THE BEEF ANIMAL AND ENERGY COST OF FATTENING



COLUMBIA, MISSOURI
JANUARY, 1919

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6-30-30

Composition of the Beef Animal and Energy Cost of Fattening

P. F. TROWBRIDGE,* C. R. MOULTON, L. D. HAIGH

OBJECT OF THE INVESTIGATION

An investigation of the composition of the mature beef animal, as influenced by fattening, and of the energy cost of fattening was made preliminary to, and as a part of, the general "Use of Food" experiment conducted at the University of Missouri Agricultural Experiment Station during the last ten years. H. J. Waters, who outlined the work, states the object of the investigation as follows:

1. To determine the chemical composition of the gain made by three-year-old steers in the process of being fattened or being fitted for the market.
2. To determine what changes take place in the form of the animal in the fattening process.
3. The fundamental question is also raised as to when a steer is just fat enough for all economic requirements, that is, for all rational demands of the consumer, and how far this differs from the condition now (December, 1907) required by the market. In other words, how much, if any, too fat are feeders required to make cattle to satisfy the demand of the consumer?

When it is realized that any excess fat beyond that which is required to make an attractive looking, juicy, and highly flavored meat is essentially waste, because the consumer will not eat it, and in consideration of the fact that this fat costs the producer a large sum of money for which the world gets no reasonable return, the importance of this question will be apparent. As conditions are now, a large amount of the corn produced in the Mississippi Valley is converted into animal fat, which is not used for human food but finds its way into the sewer or soap factory.

ACKNOWLEDGEMENT.—The data used in this bulletin have been prepared for publication and the manuscript has been written by C. R. Moulton. The data concerning the three animals, Steers 18, 121, and 48, included in this bulletin as well as in Research Bulletin 18, form part of the dissertation presented by him for the degree of Doctor of Philosophy. The method of treatment has been slightly modified, however, in order to make comparisons with later work of other investigators.

*Resigned September, 1918.

GENERAL PLAN OF THE INVESTIGATION

It was planned to select three steers about three years of age to determine the maintenance cost, then to fatten one enough to satisfy all reasonable and intelligent demands of the market, and to make a second very fat. The third was to serve as a check animal. All three were to be slaughtered and analyzed.

To complete the maintenance cost data, other animals were included in the experiment until data had been obtained on seven different animals. Two of the animals were to supply data concerning the difference in cost due to confinement in a stall or to freedom in a lot. Two others were to show the effect of a previous good condition upon this cost. The three animals first mentioned were to show the cost for thin cattle. Digestion trials were to be run with some of the animals to determine the digestibility of the ration on scant, medium, and heavy feeding.

The determination of the cost of fattening is dependent upon the determination of the cost of maintenance and the factors influencing it. These extensive maintenance trials together with those conducted with other steers have been previously reported.^{1*}

DESCRIPTION OF THE ANIMALS USED

BREED AND AGE

Table 1 gives the breed and dates of birth, of maintenance trials, and of slaughter for the seven animals.

TABLE 1.—DATES OF BIRTH, MAINTENANCE TRIALS AND SLAUGHTER

Steer	Date of birth	Breed	Date of maintenance trial	Date of slaughter
18	Apr., 1905	Grade Shorthorn	Feb. 1, 1907, to Nov. 11, 1907	Nov. 12, 1907
48	Apr., 1904	Grade Shorthorn	Feb. 1, 1907, to June 30, 1907	Jan. 18, 1909
121	Apr., 1905	Grade Shorthorn	Feb. 1, 1907, to July 10, 1907	Dec. 11, 1907
164 ¹	Apr. 1, 1906	Grade Hereford	May 12, 1907, to May 30, 1909	Nov. 8, 1909
197	Oct. 26, 1906	Registered Shorthorn	Feb. 26, 1908, to Jan. 2, 1910	Jan. 3, 1910
588	Dec. 10, 1904	Registered Angus	Feb. 1, 1907, to June 29, 1910	June 30, 1910
589	Sept. 9, 1906	Registered Angus	Feb. 6, 1908, to Aug. 28, 1909	Dec. 20, 1909

¹This animal was a ridgeling.

PREVIOUS TREATMENT AND HISTORY

Steer 18.—This animal was purchased in the late fall of 1905, dehorned, vaccinated against blackleg and turned to pasture until it was put into the winter feeding experiment of 1905-1906. Some

*This and other superior numeral references in the text are to the bibliography, page 106.

clover hay was fed the last two weeks of this grazing period. In the wintering experiment it was one of a lot of five steers receiving a ration of corn silage, wheat straw and cottonseed meal. The consumption of feed and the weight of this animal by periods are given in Table 2. The weights of the steer are for the last of each period with the exception of that in the first period which is for the first of the period. May 1, 1906, this animal was discarded because it was the poorest feeder among thirty calves. It was then grazed on a poor pasture until the close of the season and wintered in an open lot on alfalfa hay. The weights while it was on pasture are given in Table 3. On February 1, 1907, the regular experiment began.

TABLE 2.—RECORD OF STEER 18, 1905-1906

Period	Corn silage consumed lbs.	Wheat straw consumed lbs.	Cottonseed meal consumed lbs.	Weight of Steer lbs.
Dec. 22 to Jan. 20	810	123.4	90	506.7
Jan. 20 to Feb. 19	900	114.0	90	596.8
Feb. 19 to Mar. 21	988	107.0	90	646.6
Mar. 21 to Apr. 20	1140	79.4	90	682.0
Apr. 20 to Apr. 30	380	.....	30	703.3

TABLE 3.—WEIGHTS OF STEER 18 WHILE ON PASTURE, 1906

	Apr. 30	June 30	July 30	Aug. 29	Sept.	Oct. 31	Nov. 26
Lbs.	703.3	780	840	830	860	850	860

Steer 121.—The early history of Steer 121 is much the same as that of Steer 18. In the wintering experiment it was one of a lot of five steers receiving a ration of timothy hay, shelled corn, and cottonseed meal. The average consumption of feed per steer and the weight of this animal are given in Table 4. The weights of the steer are for the last of each period with the exception of the weight in the first period which is for the first of the period. In May, 1906, it was discarded for the same reason and disposed of in the same way as Steer 18. The weights while it was on pasture are given in Table 5. On February 1, 1907, the regular experiment began.

TABLE 4.—RECORD OF STEER 121, 1905-1906

Period	Timothy hay consumed lbs.	Shelled corn consumed lbs.	Cottonseed meal consumed lbs.	Weight of steer lbs.
Dec. 22 to Jan. 20	314.6	257	60	523.3
Jan. 20 to Feb. 19	194.6	282	56.6	513.3
Feb. 19 to Mar. 21	309.6	270	60	533.3
Mar. 21 to Apr. 20	350.8	270	60	590.0
Apr. 20 to Apr. 30	103.4	90	20	596.7

TABLE 5.—WEIGHTS OF STEER 121 WHILE ON PASTURE, 1906

	Apr. 30	June 30	July 30	Aug. 29	Sept.	Oct. 31	Nov. 26
Lbs.	596.7	680	735	770	795	800	840

Steer 48.—The early history of Steer 48 was the same as that of the first two animals. In the wintering experiment he was one of a lot of five steers receiving a ration of alfalfa hay and corn silage. The consumption of feed and the weight of this animal by periods are given in Table 6. The weights of the steer are for the last of each period with the exception of that in the first period which is for the first of the period. In May, 1906, this steer was discarded and treated as Steers 18 and 121. The weights while on experiment began.

TABLE 6.—RECORD OF STEER 48, 1905-1906

Period	Alfalfa hay consumed lbs.	Corn silage consumed lbs.	Weight of steer lbs.
Dec. 22 to Jan. 20	308.3	675	706.7
Jan. 20 to Feb. 19	227.2	750	671.5
Feb. 19 to Mar. 21	197.8	800	698.3
Mar. 21 to Apr. 20	314.0	934	730.0
Apr. 20 to Apr. 30	106.4	320	736.7

TABLE 7.—WEIGHTS OF STEER 48 WHILE ON PASTURE, 1906

	Apr. 30	June 30	July 30	Aug. 29	Sept.	Oct. 31	Nov. 26
Lbs.	736.7	895	930	930	940	950	920

Steer 164.—This animal was purchased in the late fall of 1906 and was used that winter in a cooperative feeding experiment. The lot of calves in which he had been placed received daily per head.

7.35 pounds of corn, 5.37 pounds of alfalfa hay, and 0.34 pounds of timothy hay. On December 8 this steer was made one of a lot of six steers receiving shelled corn, 6 parts, linseed oil meal, 1 part, and timothy hay ad libitum. The steers were kept well bedded with wheat straw. The record for this animal for the winter is shown in Table 8. The weights of the steer are for the last of each period with the exception of that in the first period which is for the first of the period. On May 12, 1907, the regular maintenance experiment began.

TABLE 8.—RECORD OF STEER 164, 1906-1907

Period	Shelled corn consumed lbs.	Linseed meal consumed lbs	Timothy hay consumed lbs.	Salt consumed lbs	Bedding used lbs.	Weight of steer lbs.
Dec. 11 to Jan. 9....	323.1	40.8	163.7	1.00	52.8	530
Jan. 10 to Feb. 8....	411.3	68.5	107.1	1.25	88.1	725
Feb. 9 to Mar. 10....	452.5	75.4	71.0	.....	73.1	790
Mar. 11 to Apr. 9....	521.5	86.9	74.8	0.80	43.3	900
Apr. 10 to Apr. 24....	270.0	45.0	27.5	0.10	22.6	945

Steer 197.—This steer was purchased in May, 1907, and was fed as a show steer. A nurse cow was provided until November 26, 1907. The steer was fed all it would eat of equal parts by measure of ground oats and bran. In addition it was fed corn and oil meal. About one-fourth pound of each was fed at first. The amount was gradually increased to about two pounds of each daily. The grain fed was moistened with sweetened water. The steer was transferred to this experiment December 28, 1907.

Steer 589.—This animal was purchased in April, 1907, and given the same general treatment as Steer 197. The weight records of these last two animals are given in Table 9. The condition of the steers may be judged from the fact that they were about one year and a quarter old at the close and weighed over one thousand pounds each. Steer 589 entered the regular experiment February 6, 1908.

TABLE 9.—WEIGHT RECORD OF STEER 197 AND STEER 589

Date 1907	Steer 197 lbs.	Steer 589 lbs.	Date 1907	Steer 197 lbs.	Steer 589 lbs.
April 17	.....	483	Aug. 17	735	778
April 27	.....	525	Aug. 24	750	803
May 4	.....	540	Aug. 31	765	831
May 11	495	542	Sept. 7	795	849
May 18	485	580	Sept. 14	808	866
May 25	505	605	Oct. 9	.....	889
June 1	544	643	Oct. 12	.....	890
June 8	555	660	Nov. 2	.....	980
June 15	580	700	Nov. 9	922	986
June 22	603	693	Nov. 16	960	1000
June 29	620	720	Nov. 23	987	1029
July 6	610	710	Nov. 30	1018	.....
July 13	.....	750	Dec. 11	1040	.....
July 20	660	771	Dec. 28	.....	1055
July 27	665	778	1908	.....	.....
Aug. 3	693	778	Jan. 25	.....	1095
Aug. 10	714	787			

Steer 588.—This steer was purchased June 7, 1906. From then until February 1, 1907, he was fed as a show steer. The daily ration consisted of crushed corn, crushed oats, linseed oil meal, cottonseed meal, bran, barley, and wheat chop. For roughage he received alfalfa hay, timothy hay, prairie hay, blue grass hay, and, during the fall and winter, corn silage. Table 10 gives the feed consumed by thirty-day periods.

TABLE 10.—FEED RECORD OF STEER 588, 1906-1907

	June 7 to July 3	July 4 to Aug. 2	Aug. 3 to Sept. 1	Sept. 2 to Oct. 1	Oct. 2 to Oct. 31	Nov. 1 to Nov. 30	Dec. 1 to Dec. 30	Dec. 31 to Jan. 31
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Corn chop offered	230	292	284.5	279	270	270	268	229.5
Oat chop offered	42.5	39.5	38.5	39	77	45	41.5	44.
Linseed oil meal offered	39	47.5	65.5	52	77	77.5	69.8	49
Bran offered	36	39.5	38.5	36	30	37.5	.....	1.3
Cottonseed meal offered	.....	.....	12.5	26	15	.....	.....	.....
Wheat chop offered	.....	.....	.....	30	30	30	30	14
Barley offered	.....	32	39	36	39	27	.....	.....
Total grain refused	12	24	54.5	52.75	56.25	78.5	58	57
Alfalfa hay consumed	89	41	11	27.5	4	37	99.5	65.5
Silage consumed	.....	.....	.....	.....	.....	107	269	246.5
Timothy hay consumed during entire period	.....	.....	.....	.....	.....	.....	.....	52
Prairie hay consumed during entire period	.....	.....	.....	.....	.....	.....	.....	47
Blue grass hay consumed during entire period	.....	.....	.....	.....	.....	.....	.....	7.5

The barley was cooked and fed as a mash. In addition to the other feeds this steer had access to pasture a part of each day. The animal weighed 886 pounds June 7 and 1192 pounds January 31. He thus made a gain of 306 pounds for the season.

QUARTERS AND GENERAL TREATMENT

At the beginning of the experiment, these steers were kept at night in the dairy barn, and during the day were given the run of a small lot. In the barn they were tied in stalls, each of which was three feet, eight inches wide and floored with plank. Sawdust was used as bedding. The lot in which they were turned during the day was long and narrow and contained about 1000 square feet. During wet weather of spring this lot became very muddy several times and it was found necessary to move the cattle to another lot which covered three-fourths of an acre.

The steers were moved, July 11, 1907, to the new shed built for this experiment. This shed faces south and has an open front. The stalls are three feet, eight inches wide, and floored with plank. Sawdust was still used as bedding. The steers were tied in the stalls at night and were given the run, during the day, of a lot containing 1400 square feet which was provided with a hydrant and water trough. Each steer had a neck strap with a brass tag giving his number.

The steers were fed hay and grain at night and grain in the morning. After they had eaten the morning feed, they were weighed and turned into the lot. They were fed at the same hour each night and morning and were weighed at the same hour each morning.

Method of Feeding.—The grain fed these steers was composed of eight parts corn chop (cracked corn) and one part linseed meal. The hay was alfalfa hay. On Feb. 1, 1907, the steers were put on maintenance, i. e., they were fed sufficient feed to maintain their body weight. The daily ration per thousand pounds varied around seven and a half pounds of grain and four-tenths as much hay. The quantity of feed was increased or lessened as was necessary to keep the body weight constant. Water and salt were given ad libitum.

Weight and feed records.—Daily records of the weights of the animals and of the weights of feed fed and feed refused were kept thruout the experiment. Representative samples of the corn, linseed meal, and alfalfa hay were taken for each lot of feed. Samples were also taken of the hay refused and grain refused. These were

all analyzed. Moisture, ash, crude protein, crude fat, crude fiber, and nitrogen-free extract were determined by the official methods of the A. O. A. C. (U. S. Dept. of Agr., Bureau of Chemistry, Bul. 107 (revised) pp. 38-56).

MAINTENANCE PERIOD

CONDITION OF ANIMALS ON MAINTENANCE

Steer 18.—At the beginning of the maintenance trial, February 1, 1907, this steer weighed 764.6 pounds. It had thus lost about one hundred pounds during the winter and was a coarse steer in very thin condition. At the end of the maintenance trial the steer weighed 778.1 pounds—average weight of the last ten days, November 2 to November 11, 1907. It was much thinner than at the beginning.

Steer 121.—This steer weighed 763.5 pounds, February 1, 1907. It had therefore lost about 80 pounds during the winter and was in very thin condition. At the end of the maintenance trial, July 10, 1907, its average weight was 764.2 pounds, but the animal was in much thinner flesh than at the beginning.

Steer 48.—On February 1, 1907, this steer weighed 840 pounds. It had lost 80 pounds during the winter and on that date was a coarse, leggy steer very thin in flesh. At the end of the maintenance trial, June 30, 1907, it weighed 841.5 pounds and was in thinner flesh than at the beginning.

Steer 164.—This animal weighed 914.5 pounds May 1, 1907, which was a few pounds lighter than it was at the end of the co-operative feeding experiment. It was a thrifty, vigorous, coarse steer of a late maturing type, in good flesh but not especially fat. By October 1, 1907, this ridgeling had changed to a coarse animal, so thin in flesh that its hooks, shoulder points and ribs showed prominently. The animal would break out at rare intervals and feed at a shock of corn, on some blue grass, or with the show cattle. It would sometimes get with the cows and even serve one. It continued becoming thinner until at the end of May, 1909, it was about as thin as Steer 18 had been but it was heavier muscled and was a larger animal.

Steer 197.—This animal lost in condition and weight when first transferred to the maintenance experiment, Dec. 28, 1907. Altho the records begin with this date it was not until about the first of February, 1908, that it was up to condition and the animal husbandmen started keeping it at constant weight. Its weight at this time

was 1088.2 pounds, and it was fat for a yearling. It was practically a finished steer but not very thickly fleshed. It showed coarseness and late maturity of type. In the market it would probably have graded as choice. On maintenance it gradually became thinner but was not as thin as Steer 164. It weighed 1079.9 pounds at the end of the experiment.

Steer 589.—This steer weighed 1066.5 pounds February 1, 1908. It was practically finished and in fairly thick flesh. It was a bit long in the legs and coarse enough to indicate late maturity. On the market it would probably have graded as prime. The steer was very nervous in temperament and would fight any of the men passing its stall. This animal was kept confined in a box stall except during a short time each day when it was taken out for exercise. Data from this steer were used in comparison with those from Steer 588 to determine the effect of confinement on cost of maintenance.

It was kept on maintenance until August 28, 1909, when it weighed 1031.3 pounds—about 35 pounds lighter than at the beginning. It was much thinner at this time than when placed on maintenance.

Steer 588.—This steer weighed 1195.8 pounds February 1, 1907. It was a prime fat steer, well finished and of blocky type. It was an especially thick fleshed steer and unusually well developed and mature for its age. While on maintenance it became considerably thinner. The rolls of fat disappeared and the shoulder blades began to be prominent. From June 20, 1909, it was fed a constant maintenance ration which was about the average required to keep it at constant weight up to that time. The following year then shows the seasonal effect upon the weight of a steer kept on a constant ration. During the last spring it gained in weight somewhat, so that about June 30, 1910, it weighed 1230 pounds.

WEIGHT CHANGES DURING MAINTENANCE

The daily weight records of the animals comprise too great a mass of data to be published here in detail. The records will consequently be given by ten-day averages. Figure 1 shows these records graphically. The first point is the average weight for the first ten days, the second point for the second ten days, and so on for each ten-day period of the experiment. The exact date or season of the year can be determined by using the data of Table 1 and calculating the time elapsed up to any desired point. The variations in weight are partly due to the season of the year and partly to the

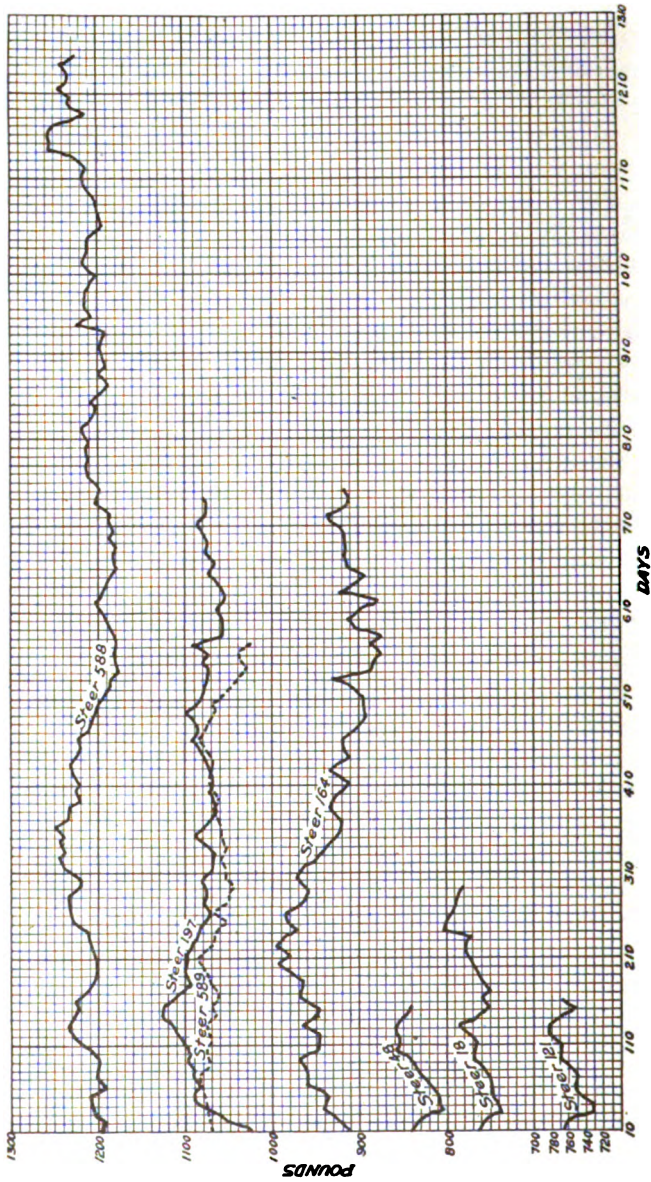


Fig. 1.—Weights of animals while on maintenance. Averages for ten-day periods

difficulty the animal husbandmen experienced in altering the amount of feed consumed from time to time to keep the weight constant. A given amount of feed would keep a steer at constant weight for a time, then a gain would become apparent. The feed would be decreased successively and yet the steer would continue to gain for a ten-day period or more. Finally the cut in feed would stop the gain in weight. Later the animal would begin to lose weight on this same ration that had allowed a previous gain. An increase in feed was thus demanded, and then this cycle would be repeated. It would seem that at some points of this chart the animal husbandmen had not succeeded very well in preventing an actual gain or loss in weight other than that caused by such factors as an abrupt change in the weather which greatly decreased or increased the water consumption.

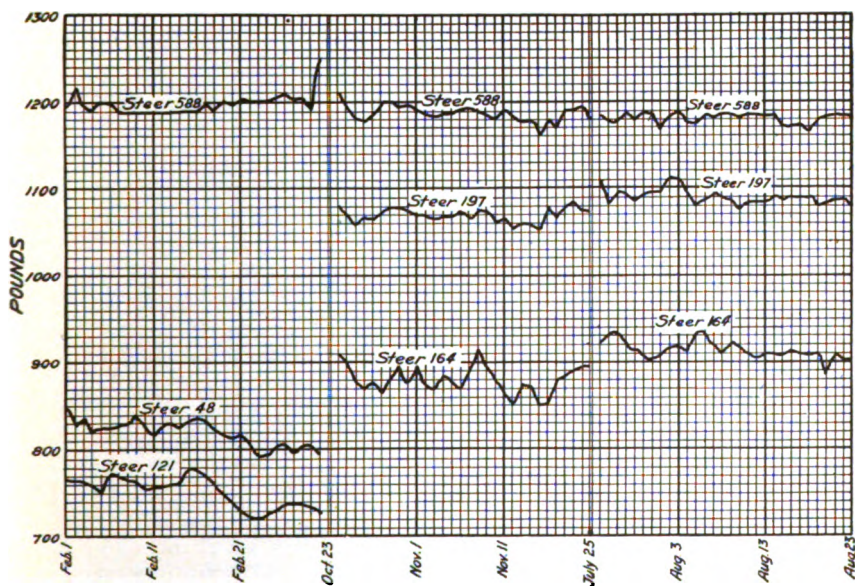


Fig. 2.—Typical daily variations in weight of animals on maintenance

In order to show how the daily weights vary the daily weights of five steers at three different seasons are plotted in Figure 2. The variations in weight from day to day are rather typical. In many cases the variations are quite marked and in other, and fewer, cases there is great constancy.

FEED CONSUMED DURING MAINTENANCE

In reporting the feed consumption of the animals in this experiment the mass of data collected, again makes it impracticable to publish

all the original records. First, there are the records of the daily consumption of hay and grain. Second, there are the tables which show the alfalfa hay, corn, and linseed consumed with the analysis of each sample and the calculated consumption of nutrients. Third, there are the tables showing the nutrients consumed by ten-day periods, by thirty-day periods, and by seasons of the year. All these tables for the seven animals dealt with here would fill a volume by themselves. Consequently only the consumption of nutrients by thirty-day periods will be presented in tabular form. Tables 11 to 17 inclusive give this data for all the animals, together with the calculated digestible nutrients. Figures 3 to 7 inclusive show graphically by ten-day periods the consumption of ether extract, crude protein, nitrogen-free extract, ash and crude fiber. The values for the latter two are so near those of the first two that a separate scale is given for them.

TABLE 11.—NUTRIENTS CONSUMED BY STEER 18 ON MAINTENANCE

Dates 1907	Crude protein lbs.	Crude fat lbs.	Nitrogen free extract lbs.	Crude fiber lbs.	Ash lbs.	Digestible crude protein lbs.	Digestible crude fat lbs.	Digestible N. F. E. lbs.	Digestible crude fiber lbs.
Feb. 1 to March 2.....	33.639	8.807	160.635	40.938	11.560	23.003	7.669	140.710	18.339
March 3 to April 1..	35.345	10.058	180.785	34.488	10.629	24.169	8.759	158.360	15.450
April 2 to May 1....	34.396	9.736	175.154	34.112	10.442	23.520	8.478	153.428	15.281
May 2 to May 31....	29.305	8.407	150.422	30.777	9.076	20.039	7.321	131.764	13.787
June 1 to June 30....	20.962	6.526	113.832	23.646	6.488	14.334	5.683	99.712	10.593
July 1 to July 30....	23.641	7.339	128.059	27.054	7.375	16.166	6.391	112.175	12.120
July 31 to Aug 29....	26.328	6.872	137.809	27.942	7.916	18.003	5.984	120.715	12.516
Aug. 30 to Sept. 28..	30.895	8.694	140.492	21.554	8.430	21.126	7.571	123.065	9.656
Sept. 29 to Oct. 28..	26.027	8.211	127.150	25.470	7.317	17.798	7.150	111.378	11.410
Oct. 29 to Nov. 11....	11.914	3.685	58.101	11.725	3.362	8.147	3.209	50.894	5.253
Total 284 days.....	272.452	78.335	1372.439	277.706	82.595	186.305	68.217	1202.202	124.407
Daily average	0.959	0.276	4.833	0.978	0.291	0.656	0.240	4.234	0.438

TABLE 12.—NUTRIENTS CONSUMED BY STEER 121 ON MAINTENANCE

Dates 1907	Crude protein lbs.	Crude fat lbs.	Nitrogen free extract lbs.	Crude fiber lbs.	Ash lbs.	Digestible crude protein lbs.	Digestible crude fat lbs.	Digestible N. F. E. lbs.	Digestible crude fiber lbs.
Feb. 1 to March 2..	34.163	8.875	162.113	42.304	11.870	23.361	7.729	142.005	18.951
March 3 to April 1..	35.345	10.058	180.785	34.488	10.603	24.169	8.759	158.361	15.450
April 2 to May 1....	34.396	9.736	175.153	34.112	10.442	23.520	8.478	153.427	15.281
May 2 to May 31....	29.403	8.305	150.699	31.003	9.134	20.106	7.232	132.006	13.902
June 1 to July 10....	28.624	8.906	155.362	32.391	8.873	19.573	7.756	136.091	14.511
Total 160 days.....	161.931	45.880	824.112	174.328	50.922	110.731	39.954	721.889	78.095
Daily average	1.012	0.287	5.151	1.070	0.318	0.692	0.250	4.512	0.488

TABLE 13.—NUTRIENTS CONSUMED BY STEER 48 ON MAINTENANCE

Dates 1907	Crude protein lbs.	Crude fat lbs.	Nitrogen free extract lbs.	Crude fiber lbs.	Ash lbs.	Digestible crude protein lbs.	Digestible crude fat lbs.	Digestible N & F. E. lbs.	Digestible crude fiber lbs.
Feb. 1 to March 2....	34.222	8.882	162.108	41.403	11.871	23.401	7.735	142.000	18.548
March 3 to April 1..	35.783	10.174	182.954	34.982	10.773	24.469	8.860	160.260	15.671
April 2 to May 1....	39.000	11.037	198.631	38.670	11.825	26.669	9.611	173.933	17.301
May 2 to May 31....	35.149	10.150	181.432	35.915	10.724	24.035	8.839	158.927	16.089
June 1 to June 30....	25.250	7.824	136.650	29.080	7.909	17.266	6.813	119.700	13.027
Total 150 days.....	169.404	48.404	861.775	180.000	53.102	115.840	41.859	754.880	80.636
Daily average	1.129	0.320	5.745	1.200	0.354	0.772	0.279	5.033	0.538

TABLE 14.—NUTRIENTS CONSUMED BY STEER 164 ON MAINTENANCE

Dates 1907	Crude protein lbs.	Crude fat lbs.	Nitrogen free extract lbs.	Crude fiber lbs.	Ash lbs.	Digestible crude protein lbs.	Digestible crude fat lbs.	Digestible N & F. E. lbs.	Digestible crude fiber lbs.
May 1 to May 30....	30.367	8.768	156.398	32.961	9.528	18.760	5.645	133.046	9.739
June 1 to June 30....	45.413	14.081	243.775	52.273	14.220	28.054	9.065	207.377	15.445
July 1 to July 30....	37.812	11.738	204.892	43.205	11.786	23.356	7.557	174.300	12.766
July 31 to Aug. 29..	35.556	9.328	187.132	37.518	10.615	21.965	6.005	159.191	11.085
Aug. 30 to Sept. 28..	41.770	11.818	190.790	39.321	11.313	25.804	7.608	162.303	8.663
Sept. 29 to Oct. 28..	38.400	12.117	187.662	37.581	10.797	23.722	7.801	159.642	11.104
Oct. 29 to Nov. 27....	35.724	11.311	175.048	34.642	9.985	22.069	7.282	148.912	10.236
Nov. 28 to Dec. 27....	34.871	11.041	170.877	33.807	9.744	21.542	7.108	145.363	9.989
Dec. 28 to Jan. 26....	30.734	11.472	154.417	32.886	8.770	18.976	7.385	131.378	9.717
Jan. 27 to Feb. 25....	26.318	13.042	132.898	29.587	7.885	16.258	8.396	113.055	8.742
Feb. 26 to March 26..	26.837	11.670	130.999	29.225	8.125	16.579	7.513	111.440	8.635
March 27 to April 25	27.106	5.240	142.134	29.109	8.183	16.745	3.373	120.912	8.601
April 26 to May 25....	27.069	5.025	142.386	29.412	8.144	16.722	3.235	121.126	8.690
May 26 to June 24....	24.650	4.178	130.605	27.029	7.299	15.228	2.690	111.104	7.986
June 25 to July 24....	25.434	5.047	133.025	27.595	7.641	15.713	3.249	113.163	8.153
July 25 to Aug. 23....	24.873	6.345	126.834	26.406	7.677	15.356	4.055	107.896	7.802
Aug. 24 to Sept. 22....	27.760	7.536	145.273	26.736	8.305	17.149	4.852	123.582	7.900
Sept. 23 to Oct. 22....	28.929	8.009	152.746	26.852	8.550	17.871	5.156	129.939	7.934

TABLE 15.—NUTRIENTS CONSUMED BY STEER 197 ON MAINTENANCE

Dates 1907-1909	Crude protein lbs.	Crude fat lbs.	Nitrogen free extract lbs.	Crude fiber lbs.	Ash lbs.	Digestible crude protein lbs.	Digestible crude fat lbs.	Digestible N. F. E. lbs.	Digestible crude fiber lbs.
Oct. 23 to Nov. 21...	28.948	7.982	151.857	27.747	8.701	17.883	5.139	129.183	8.198
Nov. 22 to Dec. 21...	32.406	9.289	170.132	30.552	9.454	20.019	5.980	144.730	9.027
Dec. 22 to Jan. 20...	33.270	10.021	173.216	32.024	9.505	20.553	6.451	147.353	9.462
Jan. 21 to Feb. 19...	33.280	10.035	173.483	31.841	9.474	20.559	6.460	147.580	9.408
Feb. 20 to March 21...	32.329	9.753	168.661	30.841	9.189	19.972	6.279	143.478	9.113
March 22 to April 20	30.581	7.577	158.614	29.347	8.668	18.892	4.878	134.931	8.671
April 21 to May 20...	25.638	5.352	131.575	26.155	7.350	15.838	3.446	111.930	7.728
May 21 to May 30...	8.488	1.773	43.578	8.637	2.430	5.244	1.141	37.071	2.552
Total 750 days.....	794.563	229.548	4079.027	803.289	233.338	490.849	147.778	3469.987	237.348
Daily average	1.059	0.306	5.439	1.071	0.311	0.654	0.197	4.627	0.316

Dates	Crude protein lbs.	Crude fat lbs.	Nitrogen free extract lbs.	Crude fiber lbs.	Ash lbs.	Digestible crude protein lbs.	Digestible crude fat lbs.	Digestible N. F. E. lbs.	Digestible crude fiber lbs.
Dec. 28 to Jan. 26....	66.324	26.055	345.633	64.225	17.420	52.066	21.382	314.730	31.594
Jan. 27 to Feb. 25....	53.418	27.870	276.225	56.981	15.396	41.934	22.862	251.528	28.031
Feb. 26 to March 26...	37.666	16.448	184.238	40.767	11.358	29.569	13.493	167.765	20.055
March 27 to April 25	36.591	7.100	192.730	38.531	11.779	28.725	5.824	175.498	18.955
April 26 to May 25...	33.254	6.238	175.457	35.563	10.499	26.105	5.117	159.769	17.495
May 26 to June 24...	27.209	4.614	141.165	29.823	8.056	21.360	3.785	131.275	14.671
June 25 to July 24...	27.053	5.366	141.488	29.361	8.129	21.237	4.402	128.838	14.444
July 25 to Aug. 23...	26.847	6.849	136.914	28.473	8.284	21.075	5.618	124.673	14.007
Aug. 24 to Sept. 22...	26.718	7.243	139.693	25.822	8.004	20.974	5.942	127.203	12.703
Sept. 23 to Oct. 22...	28.512	7.894	150.504	26.503	8.435	22.382	6.476	137.047	13.038
Oct. 23 to Nov. 21....	29.821	8.259	157.444	27.694	8.817	23.410	6.775	143.367	13.624
Nov. 22 to Dec. 21...	30.617	8.762	160.836	28.809	8.936	24.035	7.188	146.456	14.172
Dec. 22 to Jan. 20...	30.783	9.277	160.400	29.519	8.774	24.165	7.610	146.059	14.521
Jan. 21 to Feb. 19...	32.937	9.923	171.538	31.668	9.404	25.856	8.140	156.201	15.578
Feb. 20 to March 21...	35.045	10.564	182.658	33.553	9.980	27.511	8.666	166.327	16.506
March 22 to April 20	31.038	7.729	161.014	29.789	8.800	24.365	6.340	146.618	14.654
April 21 to May 20...	26.580	5.545	136.302	27.177	7.631	20.866	4.549	124.115	13.369
May 21 to June 19....	26.025	5.423	133.319	26.784	7.499	20.430	4.449	121.339	13.176

TABLE 15.—NUTRIENTS CONSUMED BY STEER 197 ON MAINTENANCE—Continued

Dates 1907	Crude protein lbs.	Crude fat lbs.	Nitrogen free extract lbs.	Crude fiber lbs.	Ash lbs.	Digestible crude protein lbs.	Digestible crude fat lbs.	Digestible N. F. E. lbs.	Digestible crude fiber lbs.
June 20 to July 19....	27.056	6.197	137.612	27.806	7.725	21.240	5.084	125.308	13.679
July 20 to Aug. 18....	28.473	7.723	141.378	29.103	7.936	22.352	6.335	128.737	14.317
Aug. 19 to Sept. 17....	30.014	8.153	149.187	30.521	8.340	23.562	6.688	135.848	15.014
Sept. 18 to Oct. 17....	35.480	9.767	171.495	33.772	9.691	27.853	8.012	156.162	16.613
Oct. 18 to Nov. 16....	37.971	10.722	177.680	31.720	9.956	29.808	8.795	161.794	15.604
Nov. 17 to Dec. 16....	37.941	10.677	177.885	31.735	9.977	29.784	8.759	161.980	15.611
Dec. 17 to Jan. 2.....	20.946	5.575	100.645	18.027	5.761	16.443	4.573	91.646	8.868
Last 677 days	704.577	186.048	3584.582	692.520	203.771	553.107	152.619	3264.084	340.671
Daily average	1.041	0.275	5.295	1.023	0.301	0.817	0.225	4.821	0.503

TABLE 16.—NUTRIENTS CONSUMED BY STEER 588 ON MAINTENANCE

Dates 1907-1910	Crude protein lbs.	Crude fat lbs.	Nitrogen free extract lbs.	Crude fiber lbs.	Ash lbs.	Digestible crude protein lbs.	Digestible N. F. E. lbs.	Digestible crude fiber lbs.	Digestible crude fat lbs.
Feb. 1 to March 2....	42.256	11.945	215.067	42.003	12.845	31.548	10.146	193.621	19.650
March 3 to April 1....	37.995	10.677	192.429	38.447	11.673	28.367	9.069	173.240	17.987
April 2 to May 1....	39.998	10.778	195.666	45.366	13.159	29.862	9.155	176.154	21.224
May 2 to May 31....	47.875	13.805	246.814	49.469	14.602	35.743	11.726	222.202	23.143
June 1 to June 30....	35.603	10.963	191.419	42.521	11.389	26.581	9.312	172.331	19.893
July 1 to July 30....	32.096	9.978	174.147	36.405	9.964	23.963	8.475	156.781	17.031
July 31 to Aug. 29....	33.009	8.676	174.091	34.482	9.795	24.644	7.369	156.731	16.132
Aug. 30 to Sept. 28....	38.592	10.965	176.945	26.350	10.379	28.812	9.313	159.300	12.327
Sept. 29 to Oct. 28....	35.366	11.184	173.141	31.402	9.905	26.404	9.499	155.865	16.094
Oct. 29 to Nov. 27....	32.823	10.343	161.197	31.542	9.119	24.505	8.785	145.122	14.756
Nov. 28 to Dec. 27....	32.287	10.214	158.114	31.378	9.036	24.105	8.676	142.347	14.680
Dec. 28 to Jan. 26....	30.734	11.472	154.437	32.886	8.770	22.946	9.744	139.037	15.385
Jan. 27 to Feb. 25....	26.460	13.085	133.743	29.614	7.910	19.755	11.114	120.406	13.854

Feb. 26 to March 26..	26.819	11.670	130.999	29.225	8.125	20.023	9.912	117.936	13.672
March 27 to April 25	27.106	5.240	142.134	29.105	8.183	20.237	4.451	127.960	13.616
April 26 to May 25..	27.079	5.025	142.385	29.412	8.144	20.217	4.268	128.186	13.760
May 26 to June 24..	26.893	4.559	142.477	29.487	7.963	20.078	3.872	128.269	13.795
June 25 to July 24....	27.159	5.422	141.263	29.984	8.254	20.277	4.605	127.176	14.027
July 25 to Aug. 23....	30.337	7.715	154.258	32.574	9.423	22.049	6.553	138.875	15.239
Aug. 24 to Sept. 22..	34.059	9.229	178.042	32.957	10.208	25.428	7.839	160.288	15.418
Sept. 23 to Oct. 22..	30.967	8.572	163.386	28.858	9.172	23.120	7.281	147.093	13.501
Oct. 23 to Nov. 21..	29.836	8.262	157.565	27.662	8.812	22.275	7.018	141.853	12.941
Nov. 22 to Dec. 21....	32.670	9.357	171.665	30.675	9.517	24.391	7.948	154.547	14.351
Dec. 22 to Jan. 20....	34.009	10.259	177.380	32.465	9.668	25.391	8.714	159.692	15.188
Jan. 21 to Feb. 19....	34.679	10.464	180.899	33.178	9.874	25.904	8.888	162.860	15.522
Feb. 20 to March 21	32.039	9.659	166.948	30.717	9.131	23.920	8.204	150.300	14.370
March 22 to April 20	28.530	7.083	155.929	27.169	8.051	21.300	6.016	140.380	12.710
April 21 to May 20....	25.432	5.315	142.280	25.774	7.267	18.987	4.514	128.092	12.058
May 21 to June 19....	25.353	5.295	141.766	25.800	7.260	18.928	4.497	127.629	12.070
June 20 to July 19....	30.934	7.011	165.030	31.557	8.798	23.095	5.955	148.573	14.763
July 20 to Aug. 18....	31.113	8.445	154.542	31.761	8.667	23.226	7.173	139.131	14.859
Aug. 19 to Sept. 17..	31.113	8.445	154.542	31.761	8.667	23.226	7.173	139.131	14.859
Sept. 18 to Oct. 17..	31.973	8.829	155.087	30.111	8.679	23.871	7.499	139.622	14.087
Oct. 18 to Nov. 16....	33.264	9.405	155.907	27.636	8.697	24.835	7.988	140.361	12.929
Nov. 17 to Dec. 16..	33.185	9.346	155.785	27.637	8.705	24.776	7.938	140.247	12.929
Dec. 16 to Jan. 15....	32.076	8.538	154.050	27.651	8.829	23.948	7.252	138.688	12.936
Jan. 16 to Feb. 14....	32.076	8.538	154.050	27.651	8.829	23.948	7.252	138.688	12.936
Feb. 15 to March 16..	32.076	8.538	154.050	27.651	8.829	23.948	7.252	138.688	12.936
March 17 to April 15	32.076	8.538	154.050	27.651	8.829	23.948	7.252	138.688	12.936
April 16 to May 15..	32.076	8.538	154.050	27.651	8.829	23.948	7.252	138.688	12.936
May 16 to June 14....	31.452	7.783	153.548	28.379	9.513	23.482	6.611	138.236	13.277
June 15 to June 29....	13.573	3.126	65.548	13.278	4.279	10.133	2.655	59.012	6.212
Total 1245 days.....	1335.066	372.291	6766.822	1310.282	387.838	996.747	316.217	6092.035	612.989
Daily average	1.072	0.299	5.435	1.052	0.312	0.800	0.254	4.893	0.492

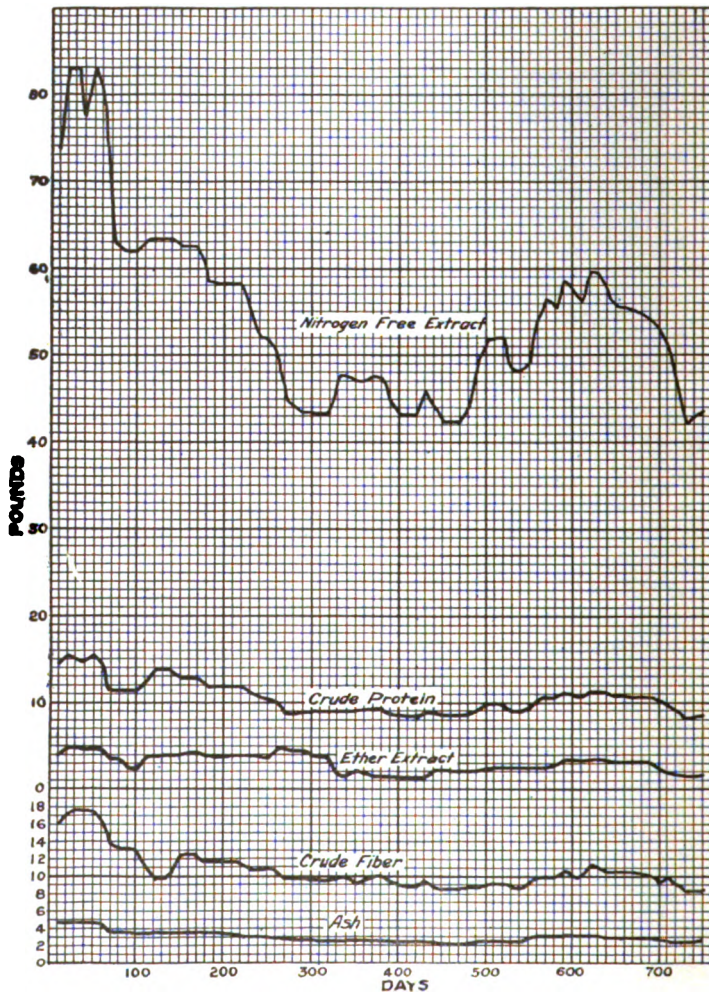


Fig 4.—Nutrients consumed by Steer 164 during maintenance.
By ten-day periods

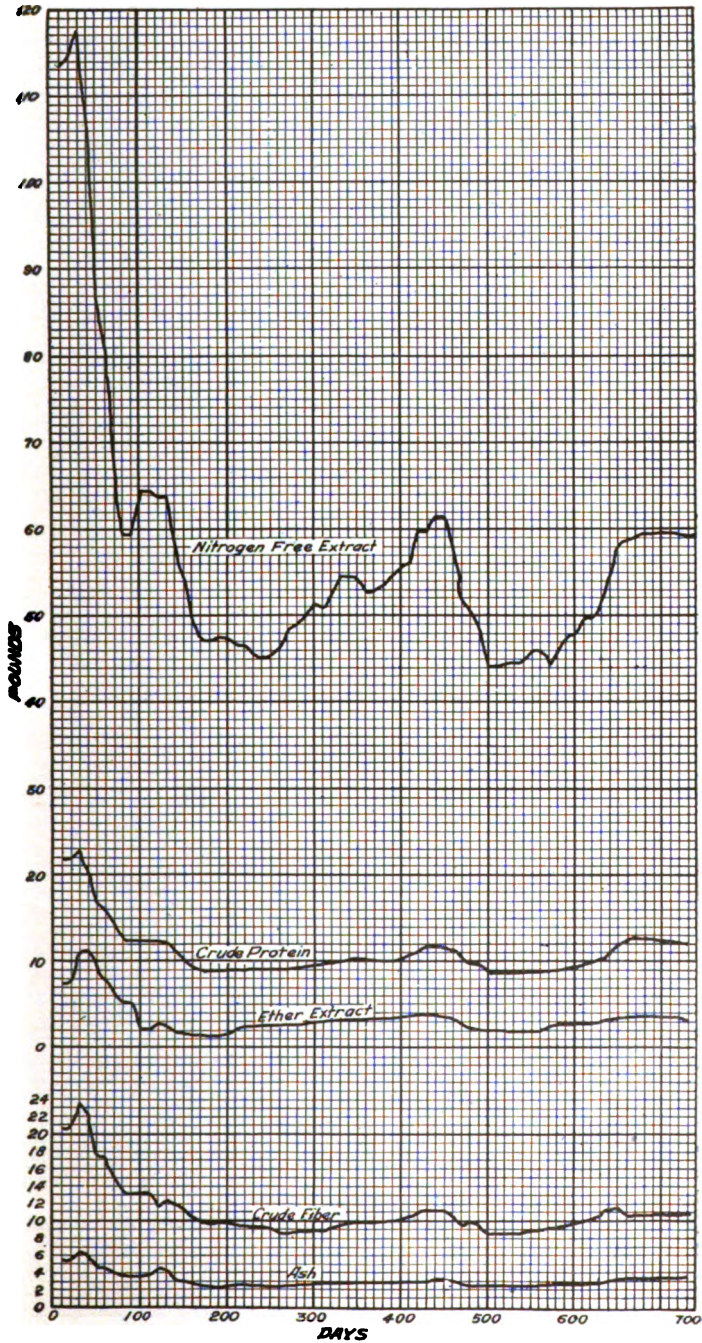


Fig. 5.—Nutrients consumed by Steer 197 during maintenance.
By ten-day periods



Fig. 6.—Nutrients consumed by Steer 588 during maintenance.
By ten-day periods.

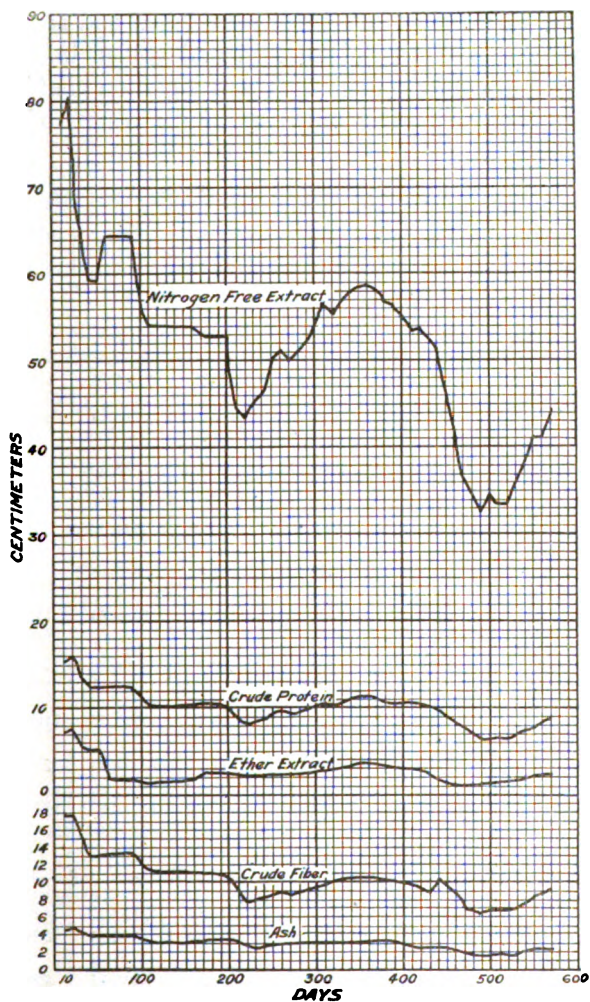


Fig. 7.—Nutrients consumed by Steer 589 during maintenance. By ten-day periods

DIGESTION TRIAL

Digestion trials had been run on most of these steers during the experiment. During the ten days of the digestion trial (when data were taken) the feces and urine were collected and analyzed and special samples of the feed consumed were taken and analyzed. From the weight of nutrients fed in the feed and voided in the feces the per cents digested were calculated. These digestion coefficients were used in the calculations. The summary of the results of these trials is given in Table 18.

TABLE 18.—DIGESTION FACTORS OF THE ANIMALS

Steer	18	48	164	197	588	588
Age, months	30	42	24 2/3	18	34 2/3	40 1/3
Length of trial, days....	10	10	10	10	10	10
Crude protein consumed, grams	3856.25	16358.31	4107.31	5558.38	4454.81	4107.31
Crude protein voided, grams	1219.31	6275.12	1570.00	1194.94	1124.50	1045.10
Crude protein digested, grams	2636.94	10083.19	2537.31	4363.44	3330.31	3062.21
Crude protein digested, per cent	68.381	61.639	61.776	78.502	74.758	74.559
Ether extract consumed, grams	1183.40	5178.10	1136.49	1544.33	1377.72	1136.49
Ether extract voided, grams	152.85	1249.56	404.84	277.48	182.16	192.08
Ether extract digested, grams	1030.55	3928.54	731.65	1266.85	1195.56	944.41
Ether extract digested per cent.....	87.084	75.868	64.378	82.032	86.778	83.098
Nitrogen free extract consumed, grams.....	18783.00	81126.67	21040.95	28573.55	21831.30	21040.95
Nitrogen free extract voided, grams	2329.77	23041.93	3141.61	2554.71	2253.76	2024.45
Nitrogen free extract digested, grams	16453.23	58084.74	17899.34	26018.84	19577.54	19016.50
Nitrogen free extract digested, per cent	87.596	71.598	85.069	91.059	89.676	90.379
Crude fiber consumed, grams	3802.79	13191.77	3829.14	5122.32	4303.44	3829.14
Crude fiber voided, grams	2099.21	7477.15	2697.74	2602.51	2088.37	2217.35
Crude fiber digested, grams	1703.58	5714.62	1131.40	2519.81	2215.07	1611.79
Crude fiber digested, per cent	44.798	43.320	29.547	49.193	51.472	42.093
Organic nutrients consumed, grams	27625.19	115854.85	30113.89	40798.58	31967.27	30113.89
Organic nutrients voided, grams	5801.14	38043.76	7814.19	6629.64	5648.79	5478.98
Organic nutrients digested, grams	21824.05	11811.09	22299.70	34168.94	26318.48	24634.91
Organic nutrients digested, per cent	79.001	67.163	74.051	83.750	82.329	81.806

Steer 164, the ridgeling, a very nervous animal, showed markedly lower digestion coefficients than the other animals. The full-fed animal, Steer 48, showed low digestion coefficients also, and in per cent of total organic nutrients digested it was the lowest of all. The very thin steer, Steer 18, had lower coefficients (excepting for the ether extract) than the two fat animals, Steer 197 and Steer 588. The details of this and other digestion trials will be published in a later bulletin. Steers 18, 164, 197, and 588 were in the digestion stalls when on maintenance. Steer 48 was in the digestion stall when on full feed. Steers 121 and 589 were not in the stalls at all. For the digestion coefficients of Steers 121 and 48 while on maintenance, the coefficients of Steer 18 were used. For Steer 589 the averages of the coefficients for Steers 588 and 197 were used. This selection was made on the basis of similar treatment, age, and condition.

REQUIREMENT FOR MAINTENANCE

A study of Figure 1 in comparison with Figures 3 to 7 brings out a few facts which must be considered before proceeding with the derivation of the maintenance cost. The consumption of total nutrients fell rapidly during the first few periods upon maintenance while the weights of the animals did not follow this decrease. This cheapening of the cost of maintenance was characteristic of all the steers and was due to the fact that the animals adjusted themselves to a low plane of nutrition and that they thereby became more economical in the use of food digested.

In the case of Steer 197, however, there was both a very marked decrease in the nutrients consumed and an increase in live weight. This is in accord with the treatment given this animal. The animal husbandman was feeding the steer to bring it back to its previous condition. Consequently the maintenance period should not have begun until after the feeding had become normal. Table 6 shows that this was accomplished only after the first 60 days of the experiment. Therefore in the following work these 60 days will not be included.

Table 19 shows the data for the maintenance costs of the seven animals. The total grain and hay consumed together with the average daily consumption and the consumption per 1000 pounds are included with the other data. In calculating this last item the needs were assumed to be proportional to the five-eighths power of the weight for the three thin steers and to the five-ninths power of the weight for the fat animals. (See page 29). Steers 197 and 589

TABLE 19.—COST OF MAINTENANCE

Steer	18	121	48	164	197	588	589
Length of trial, days	284	160	150	750	677	1245	580
Average live wt. lbs.	767	759	837	934	1082	1212	1065
Wt. grain consumed, lbs.	1633.00	976.50	1023.00	4844.93	3940.92	8024.78	3487.84
Wt. hay consumed, lbs.	690.60	428.95	445.07	1845.84	1,011.40	3245.95	1397.60
Daily grain consumed, lbs.	5.75	6.10	6.82	6.46	5.82	6.45	6.01
Daily hay consumed, lbs.	2.43	2.68	2.97	2.46	2.51	2.61	2.41
Daily grain per 1000 lbs.	6.79	7.25	7.62	6.71	5.57	5.80	5.60
Daily hay per 1000 lbs.	2.87	3.18	3.32	2.56	2.40	2.35	2.33
Total digestible organic matter consumed, lbs.	1581.13	950.67	993.22	4352.29	4310.481	8017.99	3523.79
Average daily digestible organic matter, lbs.	5.568	5.942	6.621	5.803	6.367	6.440	6.075
Average daily energy equivalent, therms.	9.577	10.220	11.388	9.981	10.951	11.077	10.449
Energy consumed per thousand lbs. weight	11.30	12.14	12.73	10.40	10.42	9.82	10.05
Energy per thousand lbs.	.....	.....	.....	10.35	10.48	9.95	10.09

¹The five eighths power of weight was used.²The five-ninths power of weight was used.

which weighed about 1000 pounds needed about six pounds of the grain mixture and two and one-half pounds of alfalfa hay for maintenance. Steer 48, altho he weighed only 837 pounds, needed 6.82 pounds of grain and 2.97 pounds of hay, which was more than the amount needed by the heaviest animal, Steer 588.

When the requirements per 1000 pounds of animal were calculated, it was found that the three heaviest steers needed from 5.54 to 5.78 pounds of grain and from 2.31 to 2.39 pounds of hay. Steers 18 and 164 were next in order of economy and needed between 6.7 and 6.8 pounds of grain and from 2.57 to 2.87 pounds of hay. Steers 121 and 48 were more expensive. An average of 6.5 pounds of grain and 2.7 pounds of hay were needed per thousand pounds of animal.

ENERGY REQUIREMENT FOR MAINTENANCE

From the total digestible organic matter consumed during maintenance the daily consumption and the energy equivalent were calculated. The figures are shown in Table 19. The energy consumption was about ten per cent lower than the figures given in Research Bulletin 18 of the Missouri Agricultural Experiment Station. This is due to the method of calculation. The former method¹ was considered the best at the time the calculations were first made, which was some time previous to the date of publication. Some of the factors for the metabolizable energy of the digestible nutrients were

obtained from work on cattle, while others were from work on the horse. The data were incomplete and some assumptions had to be made.

Since that time Armsby and Fries² in their calorimeter have worked out the energy values of various feeding stuffs when fed to cattle. Their ration called "alfalfa hay and grain mixture No. 2" was very similar to the ration fed the animals in this experiment. An average value for the metabolizable energy per kilogram of digestible organic matter consumed in this ration is 3797 Calories². This is equivalent to 3.797 therms. Since the ration used differed from the one quoted from the work of Armsby and Fries a value for it was derived by the method proposed by them (p. 451 of the article quoted). Alfalfa gives an average of 3.61 therms of metabolizable energy per kilogram of digestible organic matter. Grain mixture No. 2 has a value of 3.88 therms and the average value for the three grain rations—maize meal, wheat bran, and grain mixture No. 2—is 3.89 therms. The average value given for grain rations with less than 5 per cent of digestible fat is 3.9 therms. These figures are all very near together, and so the first of the three was used. Since the ration contained 0.4 as much alfalfa as grain the value of 3.61 was multiplied by 0.4, the value of 3.88 was multiplied by 1.0, the two were added and the sum was divided by 1.4. This method gave 3.803 therms for the ration. This is so near the value of 3.797 therms that it would seem to make no difference which value was used. For the calculations in this report the value of 3.80 therms of metabolizable energy per kilogram of digestible organic matter was used. This is equivalent to 1.72 therms per pound.

Near the bottom of Table 19 the energy consumption daily per thousand pounds of live weight is shown. In calculating from the given weight of animal to the weight of 1000 pounds the following formula was used: $T_{1000} = T_a \frac{(1000)^{5/8}}{a}$, where a is the live weight

of the animal. It has been shown by one of the authors³ that the surface areas of steers of medium or thin condition are proportional to the five-eighths power of the live weight. For very fat steers it is proportional to the five-ninths power. It is certain that Steer 588 would class as a very fat steer. It is probable that Steers 197 and 589 belong to this group, but it is not certain that Steer 164 should be so classed. The bottom line of Table 19 gives for these four steers the energy consumption per 1000 pounds calculated in proportion to the five-ninths power of the weights. Three of the steers weighed

so nearly 1000 pounds that practically no difference was shown in the energy consumption per 1000 pounds. The heaviest steer shows a somewhat larger consumption of energy per 1000 pounds. This is due to the proportionately smaller surface area shown³ by fat animals.

The three thin animals, Steers 18, 121, and 48, show high maintenance costs compared with the fat animals, Steers 164, 197, 588, and 589. Altho these thin animals were one to two years older than three of the fat animals, they were not more mature. This is shown by the weights and measurements of the steers. The lower maintenance cost of the fat cattle is then due to the fact that they had a store of fat to draw upon. The evidence presented shows that they must have drawn upon this store to a considerable extent.

The maintenance cost is based upon the digestible organic nutrients. Consequently the cost is affected by the digestion coefficients. The feeder of cattle has to count the cost in terms of feed fed and not in terms of feed digested. The three thin cattle were assumed to digest 79 per cent (the factor of Steer 18) of the total organic nutrients consumed. Three of the fat cattle had digestion factors of 82 to 84 per cent. Their decreased cost of maintenance resulted then in spite of a larger proportion of digestible organic matter. Steer 164, however, showed a digestion coefficient of only 74 per cent. If it is assumed that it should have digested as much as Steer 18, or as the fat steers, the maintenance cost would be raised to 11 therms, or to the same cost as that of Steer 18. This animal would still be much more economical than Steer 121 and Steer 48.

Steer 589, the maintenance animal in confinement, showed a higher maintenance cost than its mate, Steer 588. This could easily have been due to its nervousness, and consequently it can not be said that confinement was responsible for the difference. It is certain that confinement does not lower the cost of maintenance below that shown by an animal allowed to run in a lot.

The average maintenance cost (the five-ninths power of the weight) per thousand pounds for the fatter animals was 11.01 therms of metabolizable energy daily. It has been shown³ that an average of 52.94 per cent of the metabolizable energy of this ration is net or available energy. By applying that figure, a value of 5.83 therms of available energy is found to be the maintenance requirement. Armsby has shown⁴ an average need of 6 therms of available energy.

GROWTH OF STEERS ON MAINTENANCE

A number of measurements of height, width, and circumference and outlines of cross sections of the animals were taken at various times thruout the experiment. In Figure 8 the instruments used are shown. Besides the tape line there are standards, calipers, and the hinged wheel for cross section measurements. The special pieces of

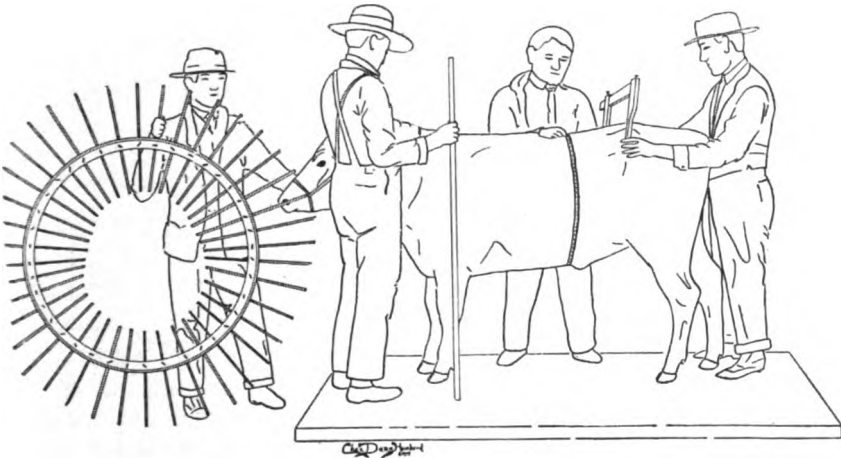


Fig. 8.—Apparatus used in taking measurements

apparatus were devised by F. G. King, now at the Indiana Agricultural Experiment Station, and J. M. Evvard, now at the Iowa Agricultural Experiment Station. The hinged wheel with its adjustable blunt prongs was used to get the exact contour of the animal at the heart, paunch, and flank. In later measurements this wheel was replaced by a chain of aluminum links adjustable at each joint by means of set-screws.

More than thirty measurements were taken of the steers at intervals of about a month. Eighteen of these have been selected. The data are shown in Tables 20 to 24. Herein are included not only the data on maintenance but also those measurements taken when the steers were on full feed.

TABLE 20.—MEASUREMENTS IN CENTIMETERS OF STEERS

Date..... Length of time elapsed	Steer 18		Steer 121		Steer 48, Full fed									
	8-17-07 0	11-9-07 2 mos 22 days	8-17-07	8-17-07	2-22-08 6 mos. 5 days	5-27-08 9 mos. 10 days	6-30-08 10 mos. 13 days	9-7-08 12 mos. 20 day.	10-1-08 13 mos. 14 days	11-3-08 14 mos. 16 days	1-30-08 15 mos. 13 days	1-2-09 16 mos. 15 days	1-16-09 17 mos.	
Condition	very thin	very thin	good to choice	.....	choice	choice	choice	choice	choice to prime	choice to prime	prime	prime	prime
Weight, pounds.....	780	787	949	.....	1312	1420	1453	1607	1667	1715	1700	1750	1800
Height at withers.....	131	135	132	.....	139	141.5	144	144	144	144	144	144	144
Height at point of shoulder to ground	.....	.....	.....	.....	98.5	100.5	100.5	100.5	101	101	101.25	101	101
Height at point midway top of hips.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Height at hind flank	135	137.5	136	.....	141	143	142.5	143	143	143	143.25	143.75	143.75
Length, high point shoulder to top point hip	107 ¹	104 ¹	103 ¹	.....	119.5	118	123	125	125	127	129	129.5	130
Width of hip.....	47	46.5	46	.....	54	57.5	58.5	59.5	59.5	60.5	60.75	60.75	60.75
Width of loin.....	.....	.....	.....	.....	44	48	47.5	50	50	51	51	51.5	52
Depth of chest.....	68.5	68	53.5	.....	79	79	80	80.5	80.5	82	82	82.5	83
Width of chest	35	37.5	39.5	.....	44	48	51.5	53.5	52.5	53	53.75	53.25	53.75
Girth at least.....	174	175.5	178	.....	213	220	220	225	224	226	227	227	233.5
Depth of paunch.....	.....	.....	.....	.....	.....	76	77	78	78.5	80	80.75	80	80.5
Width of paunch.....	.....	.....	.....	.....	.....	77	76.5	81	82	85	82	81.5	82.25
Girth of paunch.....	190.5	190.5	213	.....	241	250	252	264	261	270	266	268	270
Length of foreleg elbow to ground....	79.5	80	80	.....	81	84	84	85.5	87	86.75	86.75	86.5	86.5
Smallest circumference of fore shin bone	20	20	20	.....	21	22	21	22	21	21	21	21	21
Length poll to point of muzzle	48.5	51.5	51	.....	52	53	53	55	55.5	54.75	54.75	55	54.75
Width of jaws.....	.....	17	16	.....	19	19	20	19.75	20	20	20	20	20
Girth of throat latch	89	89	86.5	.....	99	99	100	102	57	100	100.5	100	102

¹Measurement was taken from high point shoulder to front point hips.

TABLE 21.—MEASUREMENTS IN CENTIMETERS OF STEER 164

Date.....	11-5-07 0	12-28-07 1 mo. 23 days	1-28-08 2 mos. 23 days	2-26-08 3 mos. 21 days	3-11-08 4 mos. 6 days	3-31-08 4 mos. 26 days	4-11-08 5 mos. 6 days	5-2-08 5 mos. 27 days	5-30-08 6 mos. 25 days	7-1-08 7 mos. 26 days	8-1-08 8 mos. 26 days	9-5-08 10 mos. 10 mos.	10-1-08 10 mos. 26 days
Length of time elapsed													
Condition	thin	thin	thin	thin	thin	thin	very thin	very thin	very thin	very thin	very thin	very thin	very thin
Weight, pounds.....	955	985	977	966	981	920	933	945	940	937	905	877	908
Height at withers.....	131	131	134	133.5	134	134	135	134.5	135	136	136.5	136.5	136.5
Height at point of shoulder to ground	88	90	89	88	90	93	95	92	90	91	91	90.5	91
Height at point midway top of hips.....	134	135	137	134.5	136.5	138	137.5	137	137.5	137.5	137	137.5	137.5
Height at hind flank	78	79	80	78	80	78	79	82	82	83	82.5	82	82
Length, high point shoulder to top point hips	111 ¹	112 ¹	113 ¹	112 ¹	114 ¹	110 ¹	115 ¹	114 ¹	110 ¹	116	116	117	117
Width of hip.....	46	46	47	48	48	48	48	49	48	48.5	48	49	49
Width of loin.....	37	38	38	39	39	39	38	39	38.5	38.5	39	38.5	38.5
Depth of chest.....	67.5	69	69	67	68	62	70	71	72	72.5	72	71.5	71
Width of chest.....	39	39	39	39.5	41	40	39	39	37	36.5	36	36	36
Girth at heart.....	184.5	183	183	183	183	181	182	181	180.5	182	182	179	179
Depth of paunch.....	.....	.....	.....	.....	.....	.....	.....	.....	65	66.5	66.5	64	63
Width of paunch.....	.....	.....	.....	.....	.....	.....	.....	.....	52.5	53.5	53	52	51.5
Girth of paunch.....	199	199	192	188	186	190	192	188	190.5	192.5	193	189	187
Length of foreleg, elbow to ground...	70	70	72.5	74.5	75	73	75	79	79	79	78.5	79	80
Smallest circumference of fore shin bone	21	21	20.5	20.5	21	20	20	19.5	20	20	20	20	20
Length, poll to point of muzzle.....	51.5	51.5	51.5	5.2	51	51	51	53	50	53	54.5	54.5	54.5
Width of jaws.....	.....	20	20	19	19	19	19	20	22.5	19	18.5	18.5	18.5
Girth of throat latch	99	97	99	97	96	98	100	100	93	99	98	94	94

¹Measurement was taken from high point shoulder to front point hips.

TABLE 21.—MEASUREMENTS IN CENTIMETERS OF STEER 164—Continued

Date.....	11-2-08 11 mos. 27 days	11-30-08 .2 mos. 25 days	1-2-09 .3 mos. 27 days	1-30-09 14 mos. 25 days	2-27-09 15 mos. 22 days	3-27-09 16 mos. 22 days	5-4-09 18 mos.	5-27-09 18 mos. 22 days	6-19-09 19 mos. 14 days	6-30-09 19 mos. 25 days	7-29-09 20 mos. 24 days	8-30-09 21 mos. 25 days	10-1-09 22 mos. 26 days	11-5-09 24 mos.
Length of time elapsed.														
Condition	very thin	very thin	very thin	very thin	very thin	very thin	very thin	very thin	very thin	thin	common to medium	good to choice	choice to prime	
Weight, pounds	872	874	905	900	911	925	928	916	1105	1088	1192	1295	1395	1560
Height at withers.....	138	138.25	139	139	139	139	139	139.25	139.25	139.5	139.5	140.5	141	141.5
Height at point of shoulder to ground	90.75	90.75	91.5	91.5	91.5	92	92.5	92.5	92.5	92.75	92.75	92.75	93	93
Height at point midway top of hips.....	138	138	138	138	138	138	138	138	138	138	139	139.5	143	143
Height at hind flank	84	84	84.5	84.5	84.5	84.75	84.5	84	83.5	83.5	81.5	81	81	79
Length, high point shoul- der to top point hips	117	118	116.75	116.75	116.5	117	117.25	117.5	118.5	120	120	125	124	125.5
Width of hip.....	49	49	49	49	49.5	49.5	49.75	49.75	50.5	50.75	51.75	52.5	53.5	55
Width of loin.....	39	39	39.25	39.25	39.25	39.25	39.5	39.5	40.25	40.5	41.25	42.0	45	46
Depth of chest.....	71.25	70.75	71.5	71.75	71.75	72	72.5	72.75	72.75	73.25	70	76.5	77	80
Width of chest.....	35.5	34	34.5	34.5	34.25	33.75	34	33	33.5	35.5	37	40	44.25	46
Girth at heart.....	179	177.5	180	182	182	179	177	179	185	188	194	200	206	215
Depth of paunch.....	63	62	63	63	62.5	62	62.5	62.5	66	67	70.5	72	75	80
Width of paunch.....	49.5	50	49.5	49.5	49.5	48.5	49	49	65	63	66	66	65	73.5
Girth of paunch.....	182.5	185	175	175.5	182	175	180	180.5	212	212	223	226	243	255
Length of foreleg, elbow to ground.....	70.75	80.5	80.5	80.5	80.5	81	80.5	80.5	80.5	80.75	80.75	80.75	81	81
Smallest circumference of fore shin bone	20	20	20	20	20	19.75	19.6	19.5	19.5	19.75	20.50	20.75	21	21
Length, poll to point of muzzle.....	54.5	54.5	55	55	55	55	55	55	55	55	55	55	55	55
Width of jaws.....	18.5	18.5	18.75	18.75	18.75	18.5	18.25	18.25	18.5	18.75	19	19.5	19.5	20
Girth of throat latch	94.5	94	94	94.5	94.5	94	93	92	93	95	99	100	100	105

TABLE 22.—MEASUREMENTS IN CENTIMETERS OF STEER 197

Date.....	2-1-08 0	3-30-08 1 mo. 29 days	5-30-08 3 mos. 29 days	6-30-08 4 mos. 29 days	8-3-08 6 mos. 2 days	9-5-08 7 mos. 4 days	9-29-08 7 mos. 28 days	11-2-08 9 mos. 1 day	11-30-08 9 mos. 20 days	1-2-09 11 mos. 1 day	1-30-09 11 mos. 29 days
Length of time elapsed.....											
Condition	choice	choice	good to choice	good	medium to good	medium	medium	medium to good	medium to good	me- dium+	me- dium+
Weight, pounds	1095	1097	1111	1117	1111	1070	1068	1070	1085	1069	1065
Height at withers	124.5	126.5	127	130.5	130.5	131	131.5	132	132.75	133	133
Height at point of shoulders to ground	86	87	88	88	90.5	90	91.25	91.25	91.5	91.75	91.5
Height at point midway top of hips	127	129	130	132.5	131	131.5	132	132.5	133	133	133
Height at hind flank	69	69.5	70	71	72	71	72	72.5	73.5	73.75	73.75
Length, high point of shoulder to point of hips	104 ¹	108	105	108	109	110.5	111.5	112.5	112.75	114	114.5
Width of hip	45.5	47	50	48.5	48.5	49	49	48.5	48.7	49	49
Width of loin	35.5	37	39	37.5	37	38	37.5	37.5	37.4	37.5	37.25
Depth of chest	67	68	67.5	69.5	70	70.5	70	69.5	69.5	69.5	71
Width of chest	47	48	47.5	49.5	47.5	46.5	45.5	45	45	44.25	42
Girth at heart	195.5	200	195	197	196	193.5	190	190	190	191	192
Depth of paunch .....	.....	.....	70	71.5	71	70.5	70	69.5	70	68	67.75
Width of paunch .....	.....	.....	64.5	66.5	64	63	59	59	60	58	55.5
Girth of paunch	226	222	219	221.5	220	210	210	208	209	207	205
Length of foreleg elbow to ground	74	75	75	76	76	76.5	77.25	78.25	79.5	80.25	80.25
Smallest circumference of fore shin bone	19	20	19.5	20	20	20	19.5	19.75	20	19.8	20.
Length, poll to point of muzzle	48	49	49	50	50	51.5	52.5	53	53	53.5	53.75
Width of jaws	17	19	19.5	19	20	19.5	19.5	19.5	19.25	19	19.25
Girth of throat latch	91.5	97	92	92	92	93	90.5	90	90	90	90

¹Measurement was taken from high point shoulder to front point hips.

TABLE 22.—MEASUREMENTS IN CENTIMETERS OF STEER 197—Continued

Date	2-27-09 12 mos. 26 days	3-27-09 13 mos. 26 days	5-4-09 15 mos. 3 days	5-27-09 15 mos. 26 days	6-30-09 16 mos. 29 days	7-29-09 17 mos. 30 days	9-1-09 19 mos.	10-1-09 20 mos.	11-2-09 21 mos.	12-1-09 22 mos.	1-1-10 23 mos.
Length of time elapsed	medium	good to me. lum +	good to me. lum +	me. dium +	me. dium +	medium	me. dium—	me. dium—	medium	me. dium—	me. dium—
Weight, pounds	1075	1092	1093	1090	1080	1070	1072	1066	1073	1090	1084
Height at withers	133	134.5	134.75	135	135.25	136	137.25	137.25	137.25	137.5	137.75
Height at point of shoulders to ground	91.5	92.5	93	93	93.25	93.5	93	93.5	93.5	93.75	94
Height at point midway top of hips	133.25	134.75	135	135.25	135.5	135.75	137	137.25	137.25	136.25	136.5
Height at hind flank	73.75	74	74	74.25	74.5	75.90	75.25	76.5	76.5	76.5	77
Length, high point of shoulder to point of hips	114.5	115	115	115.25	115.5	116	117	117	117	117.25	118.5
Width of hip	49	49.25	48.5	49	49	49.25	49.30	49.5	49.5	49.75	50
Width of loin	37.5	37.5	38.5	38.75	38.75	38.50	38.50	38.25	38.25	39.25	39.5
Depth of chest	71	71.25	71.75	72	72	71	71	71.5	71.5	72	72
Width of chest	42	42	42.25	41.75	41.5	40.5	41	40.75	41.75	42.5	43
Girth rt heart	193	190	190	190.5	190.5	190	191	190	190	194	195
Depth of paunch	68	67.5	65.5	66	67	67.5	69	66.75	66.75	70	67
Width of paunch	56.25	56	55.25	55.25	55	56.5	56.75	55	57	59	58
Girth of paunch	207	204	202	204	205	210	208	205	205	215	210
Length of foreleg cubow to ground	80.5	81.5	81	81	81.25	81.25	81.5	81.5	81.5	81.75	82
Smallest circumference of fore shin bone	20	19.75	19.75	19.75	20	20	20.25	20.25	20.25	20.5	20.5
Length, poll to point of muzzle	53.75	54	54.5	54.5	54.5	54.5	54.5	54.5	54.5	54.75	55
Width of jaws	19.25	19.25	19	19.25	19.25	19	19	19	19	19.5	19.5
Girth of throat latch	90	90.5	90	90	90	90	90	90.5	91	91.25	92

TABLE 23.—MEASUREMENTS IN CENTIMETERS OF STEER 589

Date.....	2-1-08		3-30-08		5-30-08		7-1-08		8-3-08		9-5-08		10-1-08		11-3-08		12-3-08		4-09	
Length of time elapsed.....	1 mo.		1 mo. 29 days		3 mos. 29 days		5 mos.		6 mos. 2 days		7 mos. 4 days		8 mos.		9 mos. 2 days		10 mos. 2 days		11 mos. 3 days	
Condition	prime	choice	choice	choice	good	medium to good	medium to good	medium to good	medium to good	medium to good	medium to good	medium to good	medium to good	medium to good	medium to good	medium to good	medium to good	medium to good	good to me- dium+	good to me- dium+
Weight, pounds	1085	1078	1067	1088	110	113	111	111.5	114	113.5	114	113.5	114	113.5	114	113.5	114	113.5	114	114
Height at withers	120.5	122.5	122	124	46.5	47	49	49.5	50	49.75	50	49.75	50	49.75	50	49.75	50	49.75	50	49.5
Height at point of shoulder to ground.....	83.5	85	84	85	39	39.5	40	40.5	40.5	40.5	40	40.5	40.5	40.5	40	40.5	40	40.5	40	40
Height at point midway top of hips.....	124	124.5	125	126.5	67.5	67.5	68	67.75	67.75	67.5	67.5	68	67.5	68	67.5	67.5	68.75	68.75	69.25	69.25
Height at hind flank	68	67.5	67	69	50.5	48.5	48.5	48	47.5	46	47.5	46	47.5	46	47.5	46	45.75	45.75	46	45.75
Height, high point of shoulder to point of hips	103 ^a	110	110	110	190	193	191	193	191	188.5	191	188.5	193	191	188.5	188	188	188	188	188
Width of hip	44	46	46.5	47	55.5	65	65	66	62	64	62	64	66	62	64	64	64	64	64	64
Width of loin	40.5	40	39	39.5	59.5	67.5	60	58	58	58.5	60	58	58	58.5	58.5	58.5	58.5	58.5	58.5	58.5
Depth of chest	69	67	67.5	68	203	224	203	206	201	202	203	206	201	201	202	202	202	202	202	202
Width of chest	50.5	50	50.5	50	70.5	72	71.5	73	73	75	71.5	73	73	75	75	75	75	75	75	75
Girth at heart	198	194	190	192	216	216	216	216	216	216	216	216	216	216	216	216	216	216	216	216
Girth at paunch .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Width of paunch .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Girth of paunch	226	209	203	216	70	72	71.5	73	73	75	71.5	73	73	75	75	75	75	75	75	75
Length of foreleg, elbow to ground.....	70	69	70	70.5	20	20	20	20.5	20	20	20	20.5	20	20	20	20	20	20	20	20.25
Smallest circumference of forearm bone	20	19	19.5	20	48.5	49	50	50	51	51.6	51	50	50	51	51	51.6	51.6	51.6	51.5	51.5
Length poll to point of muzzle.....	47	47	48	48.5	20	19.5	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Length poll to point of muzzle.....	18	19	20	20	98	98	98	95	98	96	96	95	95	96	96	95.75	95.75	95.75	96	96
Width of jaws .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Girth of throat lat.h	95	97	98	98	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

^aMeasurement was taken from high point shoulder to front point hip.

^aMeasurement was taken from high point shoulder to front point hip.

TABLE 23.—MEASUREMENTS IN CENTIMETERS OF STEER 589—Continued

Date.....	1-30-09 11 mos. 29 days	2-27-09 12 mos. 26 days	3-27-09 13 mos. 26 days	5-5-09 15 mos. 4 days	5-27-09 15 mos. 26 days	6-30-09 16 mos. 29 days	7-29-09 17 mos. 28 days	9-1-09 19 mos.	10-1-09 20 mos.	11-2-09 21 mos. 1 day	11-30-09 21 mos. 29 days
Length of time elapsed.....											
Condition	good to me- dium+	good to me- dium+	good to me- dium+	good to me- dium+	me- dium+	me- dium+	medium		good L		
Weight, pounds	1060	1064	1081	1090	1082	1047	1041	1054	1164	1290	1400
Height at withers	127.5	127.5	128	128	128	128.5	130.25	130.75	131	133.5	133.75
Height at point of shoulder to ground	86.5	86.5	86	87	87	87.25	87	87	87	88	88.5
Height at point midway top of hips	129.5	129.5	130	130.25	130.5	130.5	131.5	132	132.5	133.75	133.75
Height at hind flank	72.75	72.75	73	73.5	73.75	73.75	76.25	76.50	76	76	76
Height, high point of shoulder to point of hips	114	114	114.5	113	113	113.5	113.5	114	115	116.5	117.5
Width of hip	49.5	49.5	49.5	48.75	49	49	49	49	51	53	55
Width of loin	40.25	40.25	40.25	40	40.25	40.25	39	39	43	44	44.75
Depth of chest	69.75	69.75	70	70	70.5	70.5	69.5	69.5	71	72.25	74
Width of chest	45.75	45.5	44.25	44.75	42.75	44	42.75	41.75	46.5	48.5	49.5
Girth at heart.....	191	190	189	187	188	188	190	189	198	206	210
Depth of paunch.....	63.5	64	63.5	64	64.5	65	67	65	73.5	76	74.25
Width of paunch	58	60	58	57	56.75	56	56	59.5	71.5	76	72
Girth of paunch	199	207	202	200	204	207	205	210	243	253	243
Length of foreleg, elbow to ground.....	75	75	75.75	75.5	75.5	75.75	76	76	76	76.25	76.5
Smallest circumference of foreshin bone	20.25	20.75	19.75	19.75	20	20	20	20	20.25	21	22
Length poll to point of muzzle.....	51.5	51.5	57.75	52	52	52	52.50	53	54	54	54.25
Width of jaws.....	20	19.75	19.5	19.75	19.75	19.75	19.75	19.75	20.5	20.75	21
Girth of throat latch.....	96	96	95	95	95	95	93.50	93.50	98	98.5	100

TABLE 24.—MEASUREMENTS IN CENTIMETERS OF STEER 588

Date.....	7-29-07	11-16-07	2-22-08	5-27-08	6-30-08	8-3-08	9-7-08	10-1-08	11-3-08	11-30-08	1-2-09	1-30-09	2-27-09	3-27-09
Length of time elapsed.....	0	3 mos. 17 days	6 mos. 23 days	9 mos. 28 days	11 mos. 1 day	12 mos. 4 days	13 mos. 8 days	14 mo. 2 days	15 mos. 4 days	16 mos. 1 day	17 mos. 3 days	18 mos. 1 day	18 mos. 28 days	19 mos. 20 days
Condition	prime	choice	choice	choice	good to choice	good to choice	good to choice	good to choice	good+	good+	good+	good+	good+	good+
Weight, pounds.....	1201	1217	1230	1215	1188	1190	1200	1180	1180	1184	1197	1192	1214	1222
Height at withers.....	125	127.5	126	125	126.5	127.5	130	130.5	129	129.5	130.25	130.5	130.5	130.5
Height at point of shoulders to ground.....	.....	.....	85	80	80.5	84	86.5	86.5	86	85.75	86	86	86	85.6
Height at point mid- way top of hips.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Height at hind flank.....	131.5	131.5	132	130.5	132.5	130	131.5	132	131.5	132	132.5	132.5	132.5	132.5
Length, high point of shoulder to top point of hips.....	67.5	71	67	69.5	70	70	70	70.5	71	72	71.5	71.25	71.25	71
Width of hip.....	114 ¹	109.5	112 ¹	115	113 ¹	113 ¹	112 ¹	118.5	119.5	120.25	120.5	121	121	121.5
Width of loin.....	49.5	51	51	51	51.5	51.5	52.5	53.5	53.5	53.5	53	53	53.25	53.25
Depth of chest.....	77.5	74	74.5	74	73.5	74.5	74	73.5	73.5	73	73.5	74	74	74
Width of chest.....	.....	.....	54.5	50	52.5	50.5	49.5	48.5	48.5	48	46.5	46	46	46.25
Girth at heart.....	216	216	216	212	206	205	205	208	206	207	207	207	209	206
Depth of paunch.....	.....	.....	.....	73	73.5	70	71	69	69	68.5	65.5	66	69	68.5
Width of paunch.....	.....	.....	.....	69.5	69	70	69	68	66	70	66.5	66	68	63
Girth of paunch.....	243.5	238.5	235	231	230	231	229	225	223	225	219	219	231	222
Length of foreleg elbow to ground.....	73.5	73.5	70	72	72	72	74	75	75	75.2	75	75	75	75
Smallest circumfer- ence of fore shin bone.....	20.5	20.5	20	21	20	20	20.25	20	20	20	20	20	20	20
Length, from poll to point of muzzle.....	51	53	51	53	53	53	52.5	52.5	53	53.4	54.5	54.5	54.5	54.75
Width of jaws.....	22.5	20.5	18	20	20	20	20	20	20	20	19.6	19.6	19.6	19.75
Girth of throat latch	99	102	95.5	91	93	94	93	95	96.5	96.5	96	95	95	96.5

¹Measurement was taken from high point shoulder to front point hips.

TABLE 24.—MEASUREMENTS IN CENTIMETERS OF STEER 588—Continued

Date.....	5-4-09 21 mos 5 days	6-30-09 23 mos 1 day	7-29-09 24 mos.	9-1-09 25 mos. 2 days	10-1-09 26 mos. 2 days	11-2-09 27 mos. 3 days	12-1-09 28 mos. 2 days	1-1-10 29 mos. 2 days	2-4-10 30 mos. 5 days	3-5-10 31 mos. 6 days	4-2-10 32 mos. 3 days	5-7-10 33 mos. 8 days	6-1-10 34 mos. 2 days
Length of time elapsed.....													
Condition	good	good+	good—	good—	good—	good	good	good—	good—	good—	good+	good+	good+
Weight, pounds.....	1214	1205	1190	1210	1210	1210	1213	1202	1220	1250	1252	1210	1242
Height at withers.....	130.5	130.5	130.6	131	131.25	131.5	131.5	132	132.5	133.5	133.5	133.75	134
Height at point of shoulders to ground.....	85.75	86	86	86	86	86	86.25	86.5	86.5	86.5	87	87	87.25
Height at point mid- way top of hips.....	132.5	132.5	132.75	132.75	133	133.25	133.5	133.5	133.5	133.5	133.25	133.75	134.25
Height at hind flank.....	71	71.5	72	72	72	72	72.25	73	73	73	73	73.75	73.5
Length, high point of shoulder to top point of hips.....	121	121	120.5	120.5	120	120	120.25	120.5	120.5	121	121.25	121.5	121
Width of hip.....	52.5	52.5	52.5	52.5	52.75	52.75	53.5	53.5	53	53.5	53.75	54	55
Width of loin.....	43.5	43.5	42.75	42.25	43	43.25	43.75	44	43	43.5	43.5	43.5	43.5
Depth of chest.....	74	74	74	74	73.25	74	74.5	75.25	75.75	74.5	75	75.5	76
Width of chest.....	45.75	45.5	45	44.75	46	46	46.5	47	46	47.5	46.5	46.5	47
Girth at heart.....	203	204	205	204	205	206	212	205	207	205	207	209	209.75
Depth of paunch.....	68	68.5	69	70.5	70.5	70.5	71	72	70	71.5	71	70.75	71.75
Width of paunch.....	60.5	62	65.25	66	64.25	63.25	65.5	66	64	62	63	61	63.5
Girth of paunch.....	215	229	226.75	229	224	220	232	220	220	225	227	228	229
Length of foreleg elbow to ground.....	74.75	75	74.75	75	75	75	75.25	75.5	76	76	76	77	77
Smallest circumfer- ence of fore thin bone	19.5	20	19.75	20	20.25	20.25	20.5	20.5	20.5	20	20	20.5	20.5
Length, from poll to point of muzzle.....	54.5	54.5	54.25	54.5	54.5	54.75	55	55	55	55	55	55	56
Width of jaws.....	19.25	19.5	19.5	19.5	19.75	19.75	19.75	20	20	20	20.25	20.25	20
Girth of throat l.s.b	96	94.5	94	94	94.5	95	95.25	96	96	94	95	95	95

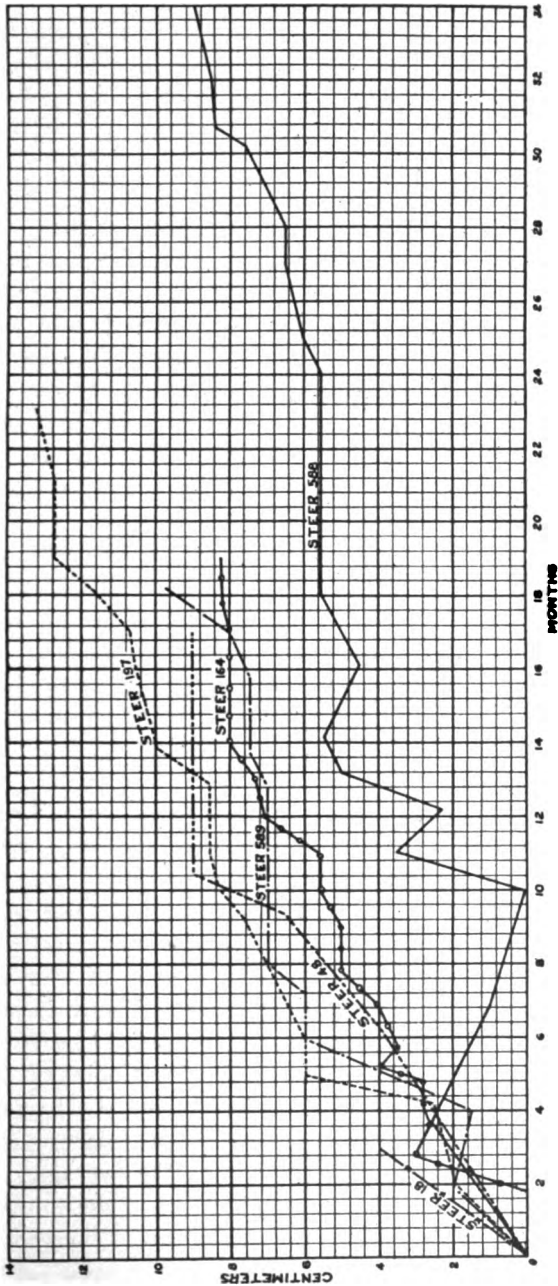


Fig. 9.—Changes in height at withers during maintenance

Gain in height at withers.—The changes in the measurements are shown graphically so that the data may be studied better. The comparative growth of animals is better shown by changes in the measurements rather than by the actual measurements themselves. Figure 9 shows the gain in height at withers of the animals upon maintenance. The rate of gain varies somewhat, but it is about the same for the three youngest animals, Steers 164, 197, and 589. These were about one and one-half years old at the beginning of the trial. Steers 18 and 588 were about two and one-half years old and Steer 48 was about three and one-half years old. This last steer, however, was on full feed during all the time represented by the measurements given in Table 11. It is seen in Figure 9 that the three young steers on maintenance gained in height as rapidly as the full fed, old steer. Since they were younger it is very probable that their impulse for growth was greater than that of Steer 48. The better plane of living of the latter seems to have been sufficient compensation for this handicap.

Steer 588 was a year older than the young steers, and so had already obtained more of its growth. The rate of gain was slower and it took 34 months for him to make the same gain made by the young steers in 17 to 18 months.

There is but one set of measurements for Steer 121 and two sets for Steer 18. Other measurements were consumed in a fire during the winter of 1907 and 1908 which destroyed the Dean's residence and some outlying buildings. The measurements of Steer 18 are shown, but since they are so few it is necessary to be cautious in drawing conclusions from them. This steer showed a rapid rate of gain. It had been on scant rations for some time before this experiment began, and so it had not obtained nearly as much of its growth as any of the other animals. This is borne out by the relative weights.

Gain in length, shoulder to hips.—Figure 10 shows the gains made by the steers on maintenance in length of body from the shoulders to the hips. The first measurements of this sort were taken from the high point of the shoulder to the front point of the hips. It was very difficult to get a reliable measurement of this distance since the animal was prone to stand crooked. Later this was compensated for by measuring on both sides and taking the average. Finally the distance from the high point of the shoulder to the top point of the hips was taken as a more reliable measurement. The records are not clear just when these changes were made. The tables show whether the front point or top point of the hips was used. Since all the

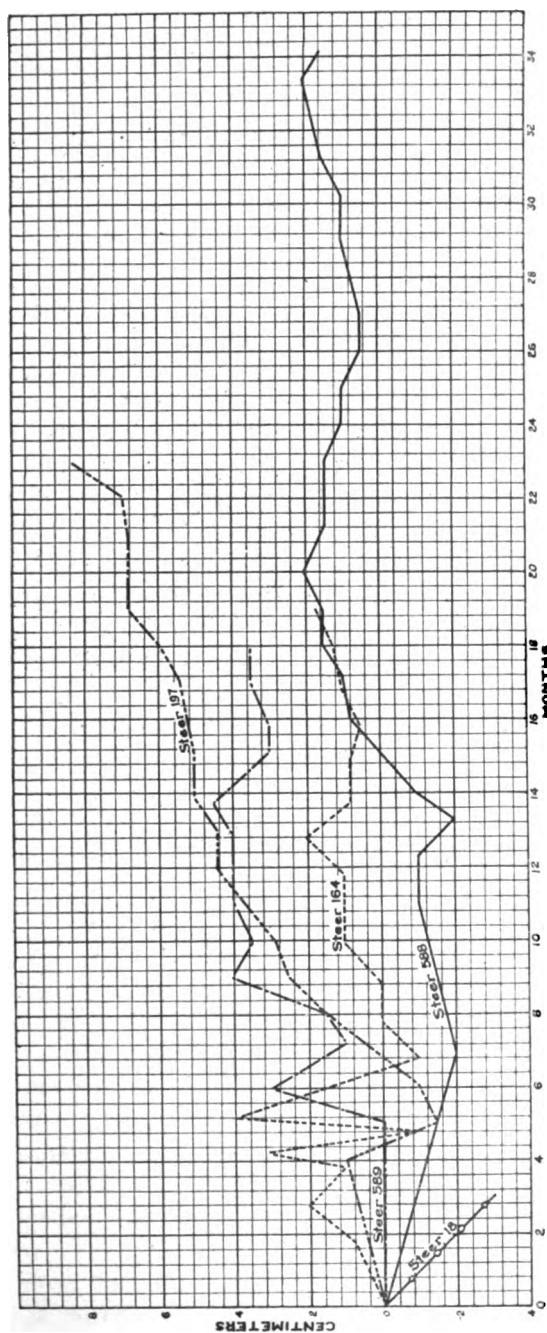


Fig. 10.—Changes in length from shoulder to hips during maintenance

later measurements were to the top point and since this was always a greater distance than to the front point a correction has been made equal to the average distance between the two measurements. The results are shown in Figure 10.

The irregularities of the curves in Figure 10 are due to causes mentioned in the preceding paragraph. The young steers made the greatest gains in length. The greatest gain was a little more than 8 centimeters in 23 months and was made by Steer 197. Steer 18 showed a loss, which may be an error. Steer 588, the two and one-half-year-old fat animal, made little change in length. A loss was later counterbalanced by a gain in length.

Gain in width of the hips.—Figure 11 shows the gain in width of the hips. The rate of gain for the young steers was again found the greatest at first. But by the end of eighteen months the older fat animal, Steer 588, had caught up with two of them. However, at the end of 34 months it had made but little more gain (5 centimeters) than Steer 589 made in 18 months. Steer 18 made a slight loss which might be considered no change at all.

Changes in heart girth.—The three measurements just discussed are measures of skeletal growth and were affected but slightly by changes in flesh or fatness. They indicated decided growth of skeleton when the animals were on maintenance.

Figure 12 shows the changes in the girth of the body in the region of the heart. All the steers lost weight, altho during the first two months Steer 197 almost made up its loss. Since skeletal growth has been proved, this loss must have been due to loss of fat, or flesh. At the end of 18 months the loss was from 5 to 7 centimeters. Steer 588 showed a loss of 13 centimeters at the end of 22 months. During the following 12 months he gained. It will be remembered that during the last year of this animal's life it was fed a ration equal to the average ration during its preceding history and that upon this average ration it gained weight. This explains the gain in heart girth.

Changes in paunch girth.—Figure 13 shows the changes in the girth of the body around the paunch. This measurement was affected partly by the fatness of the animal and partly by its fill. The great variations in this girth were due to differences in fill, or distension of the paunch due to excess of water, food, or gas, or a combination of these. The losses were considerable, and by the end of 18 months they amounted to 15 to 20 centimeters. At the end of 11 months Steer 589 showed a loss of 32.5 centimeters, which was later reduced. At the end of 22 months Steer 588 showed a loss of 28.5

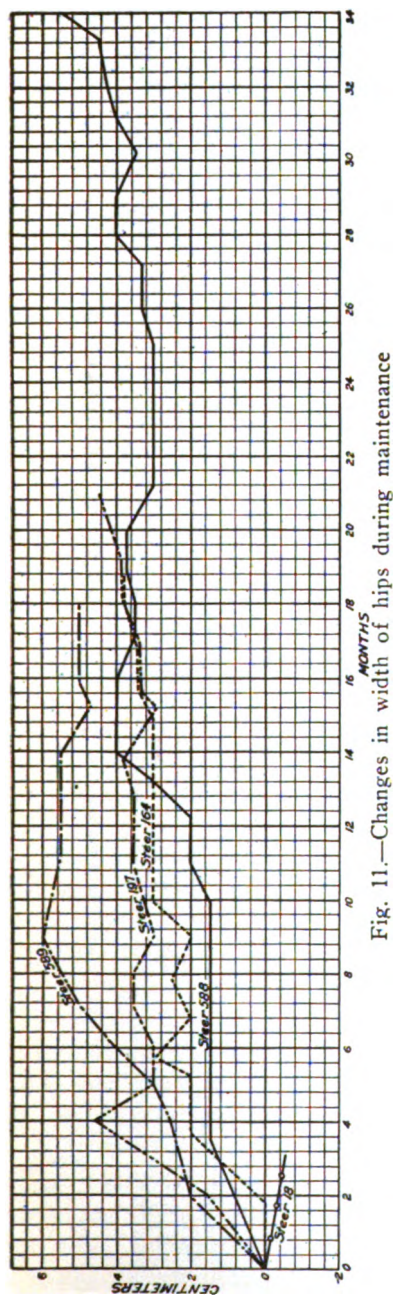


Fig. 11.—Changes in width of hips during maintenance

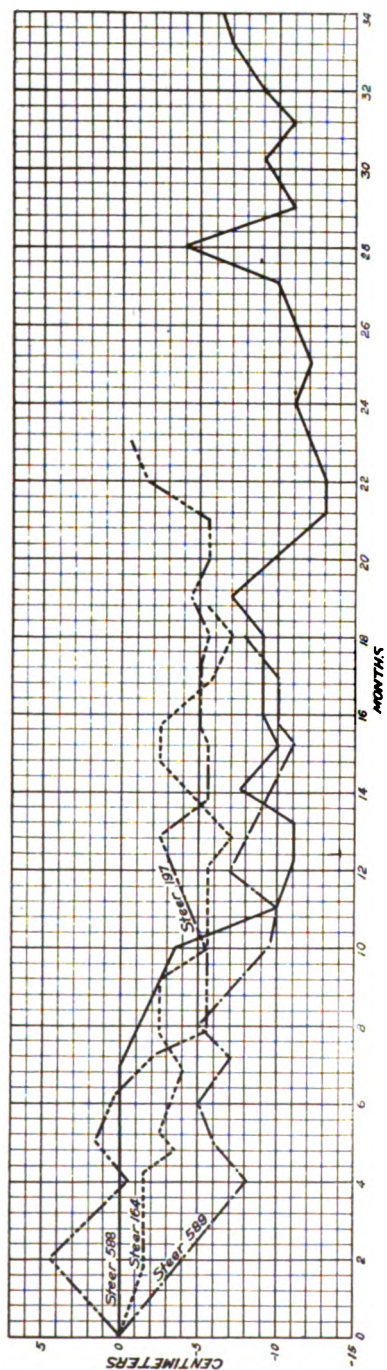


Fig. 12.—Changes in girth at heart during maintenance

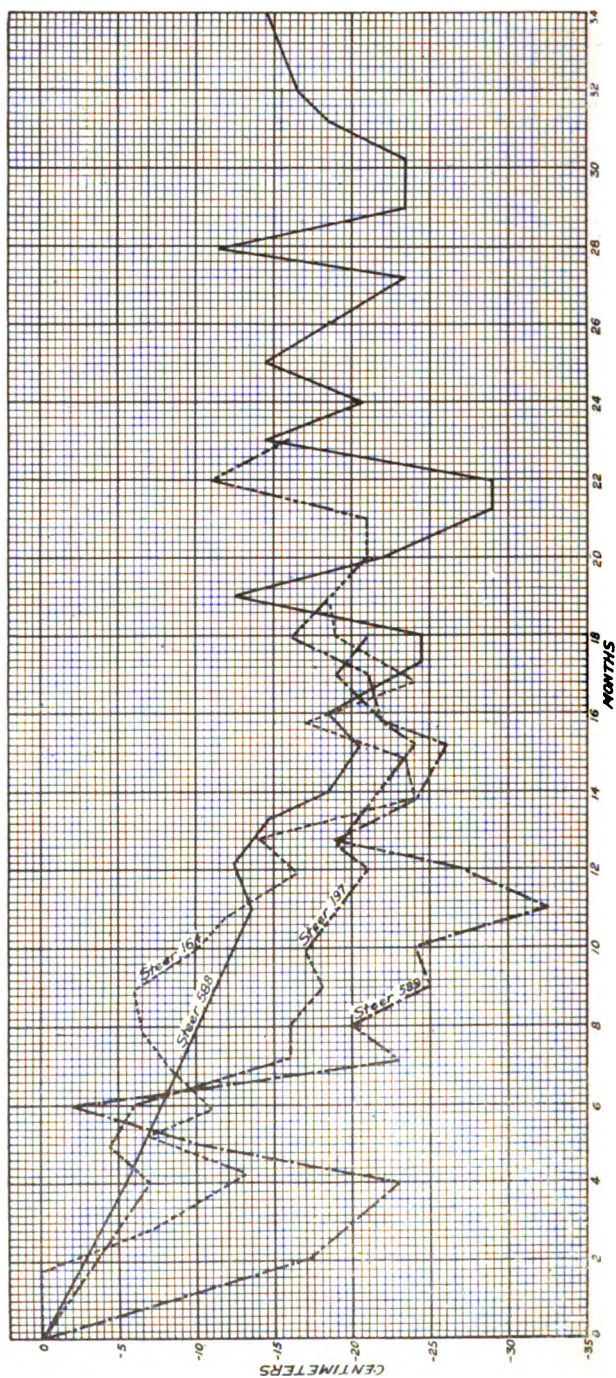


Fig. 13.—Changes in girth at paunch during maintenance

centimeters. The ensuing gain shown by this animal is explained in the foregoing discussion.

Changes in cross section.—Figures 14, 15 and 16 show the cross sections of the animals at the region of the heart and paunch. The cross sections for Steer 121 and Steer 48 were taken at the beginning and end of full feed only. For Steers 18, 197, and 588 they were taken at the beginning and end of maintenance. For Steers 164 and 589 they were taken at the beginning and end of maintenance and at the end of full feed.

The striking features of these cross sections are that maintenance adds angularity to the cross section, decreases its area, and raises the height of the cross section from the base, or ground line. This latter is due to the growth in length of the legs.

Photographs of animals.—Plates I to VII show photographs of the animals taken about the time of the cross section. Some photographs are not shown because they were taken on a much smaller scale than the others; and so they will not serve for comparison.

The thinning down of the steers on maintenance is not in every case apparent. Neither is the growth in height. The season of the year affects the coat of hair, and so the appearance is changed and a thinning down may be obscured. The photographs of all but the first two animals show these points very clearly.

FULL FEED PERIOD

TREATMENT OF THE ANIMALS

Steer 121.—This animal was selected at the end of 160 days of maintenance as one of the two animals to be used for the study of fattening. From July 11, 1907, the feed of this steer was gradually raised in quantity until the animal reached maximum consumption. The steer was continued on full feed until December 10, 1907, when it weighed 1266.4 pounds (average of last five days). During the last ten days of maintenance the steer had weighed 764.2 pounds. It had thus gained 502.2 pounds in 153 days. On December 11, 1907, this steer was slaughtered for analysis. The animal was at this time exceedingly thrifty and was gaining about three pounds a day. It was making good use of its food and was not showing excessive cost of gains made. It would have graded as choice and lacked perhaps 40 to 50 days of being in prime condition.

Steer 48.—This steer was the second animal selected for fattening. From July 1, 1907, the feed was gradually increased until the

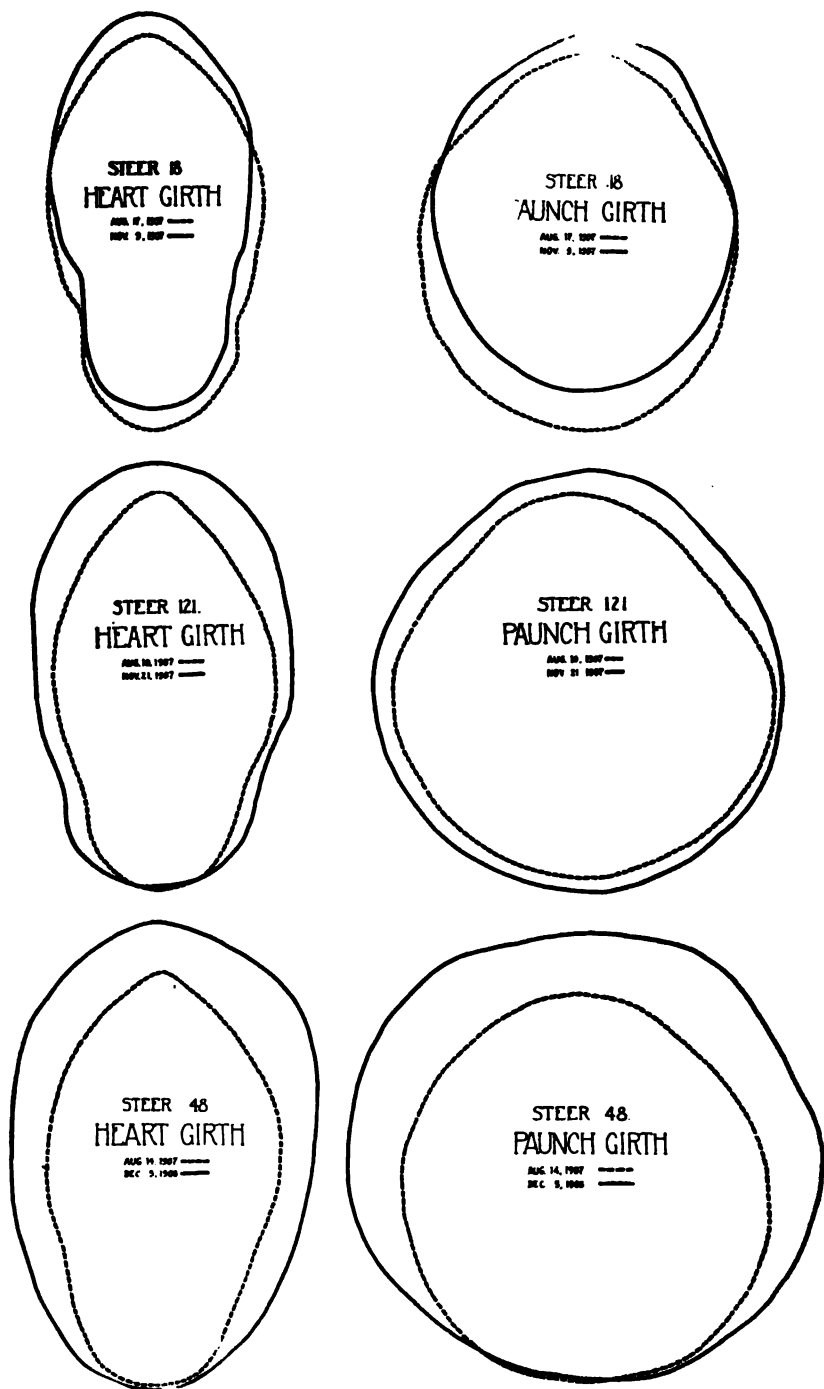


Fig. 14.—Cross-sections of Steers 18, 121, and 48

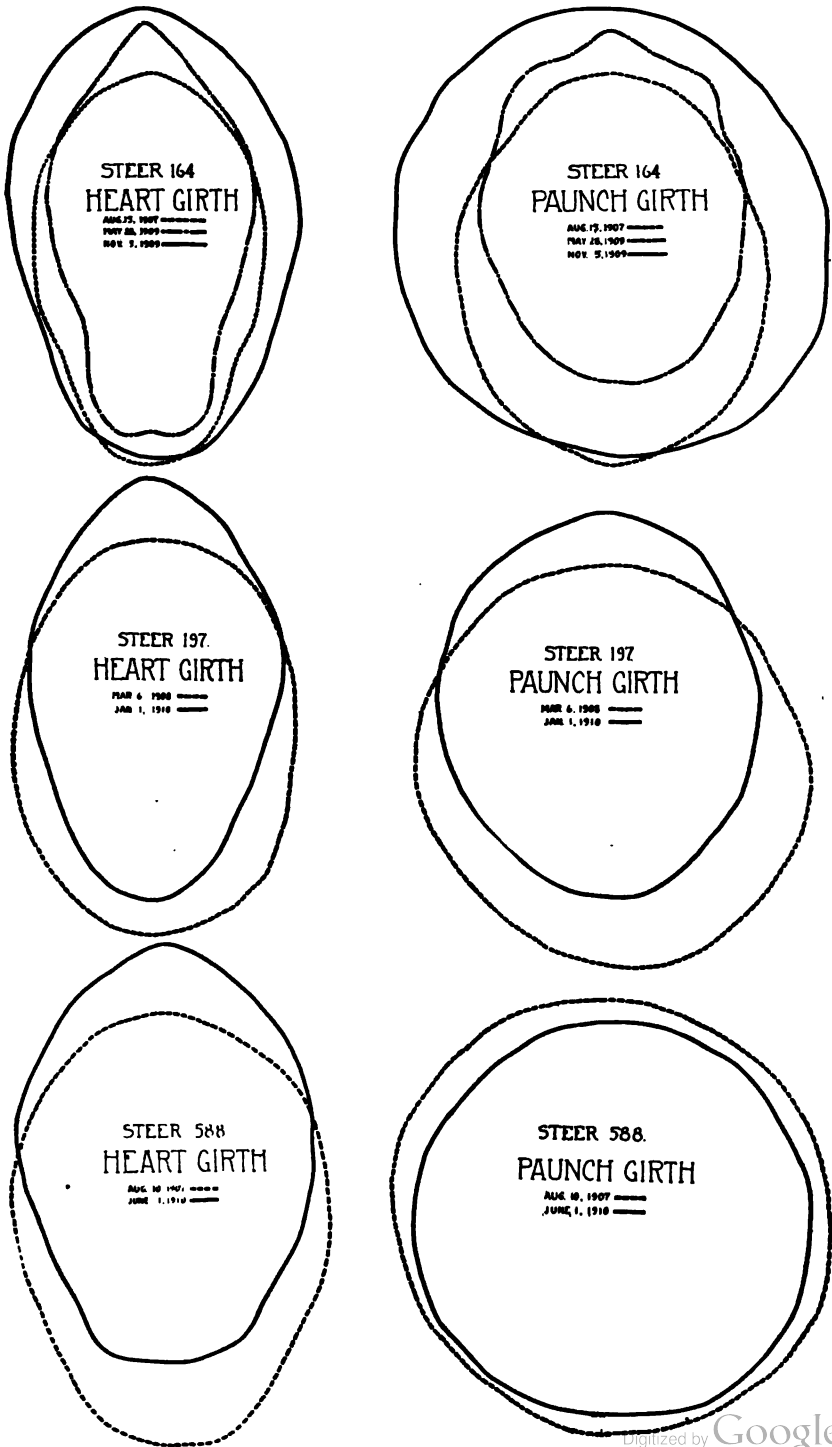


Fig. 15—Cross-sections of Steers 164, 197, and 588

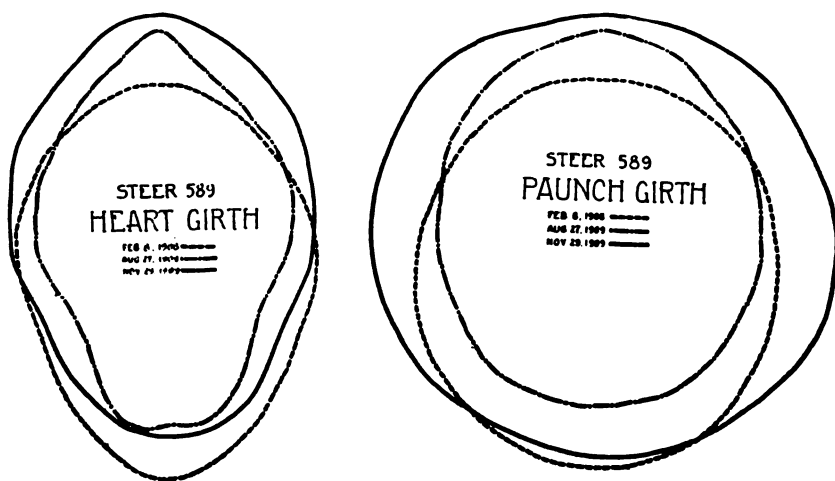


Fig. 16.—Cross-sections of Steer 589

steer reached full feed. In the middle of November, 1907, this steer showed lack of appetite and had a bad cough, which was a result of cold contracted in the digestion stalls. It was blanketed for several nights, but its cough still continued into December. On December 19 the tuberculin test was made. The steer showed a high temperature, but gave no reaction for tuberculosis. From then until January 15, 1908, it was fed all the hay it would eat. No attempt was made to keep the amount of hay and grain at the usual proportion. At this time the steer recovered and soon was gaining weight and eating heartily. In May the steer was again off feed and out of condition. Toward the latter part of the summer it picked up and its appetite returned. This animal was kept on full feed thru January 17, 1909, when it weighed 1805 pounds (average of last five days including day of slaughter). The weight for the last ten days of maintenance was 841.5 pounds. It had thus gained 963.5 pounds in 567 days. The steer was in prime condition. On January 18, 1909, it was slaughtered for analysis.

Steer 164.—This steer was full fed at the close of a long maintenance period merely to get a carcass more profitable to sell. It was gradually put upon full feed from May 31, 1909, to November 7, 1909. The weight for the last ten days of maintenance was 921 pounds and for the last five days of the full feed period, 1552.8 pounds. It had thus gained 631.7 pounds in 161 days. On November 8 the steer was slaughtered. At this time the animal was in

good condition but lacked between 30 to 50 days of being in prime, or finished, condition. At the beginning of full feed it compared well with Steer 18 and at the close it was very similar to Steer 121 when slaughtered.

Steer 589.—This animal was full fed at the close of a long maintenance period for the same reason that governed the treatment of Steer 164. It was put upon full feed beginning August 29, 1909, when it weighed 1031.3 pounds. The full feeding period ended December 19, 1909. The animal was slaughtered December 20, 1909.

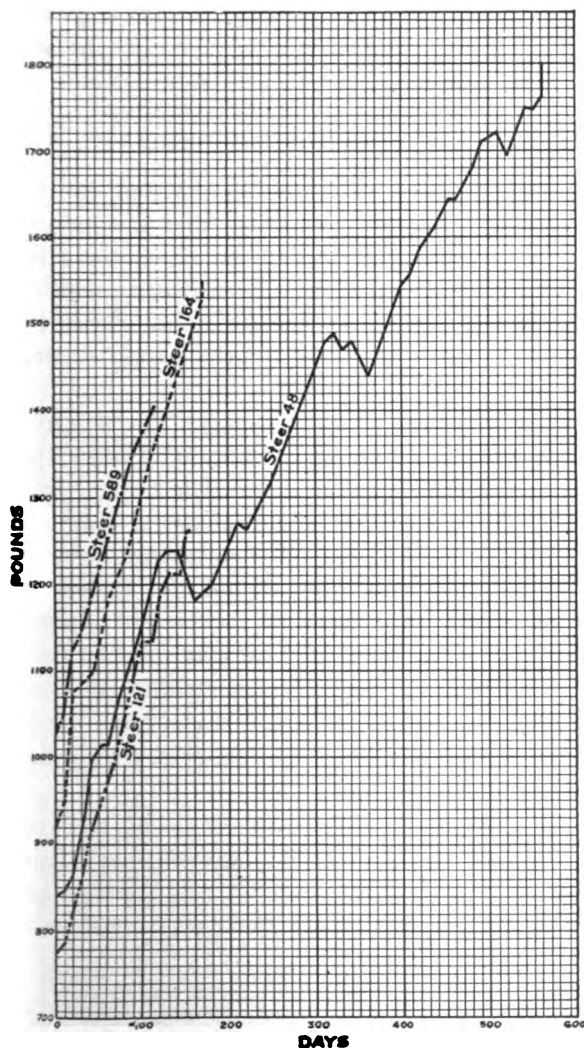


Fig. 17.—Weights of animals during growth. Averages for ten-day periods

Its average weight for the last five days was 1405.5 pounds. It had consequently gained 374.2 pounds in 113 days. In condition it was very similar to Steer 121 and Steer 164.

GAIN IN WEIGHT DURING FULL FEED

The four steers that were on full feed gained rapidly and consistently for 120 to 160 days. The rate of gain for all the animals was about the same. Figure 17 shows graphically the weight records by ten-day periods. The zero point is the weight for the last ten

days of maintenance. The following points are the average weights for each ten-day period. At the end of 120 days Steer 48 had its first trouble which resulted in diminished gain and then a considerable loss. It recovered, however, and then gained for 150 days at a somewhat slower rate than during the first period. Then the trouble was repeated. After the last recovery it gained again for 207 days with only a slight break near the end. The rate of gain during this third period was a little slower than during the second period. These slower rates of gain may have been due somewhat to the ill health of the steer but it is certain that part of it at least was due to the slower rate always noticeable after a steer has become mature and partly fat. The later gains are always more costly.

FEED CONSUMPTION DURING FULL FEED

Tables 25 to 28 give the nutrients consumed by the four full fed steers by thirty-day periods. These figures show that the animals took from 30 to 60 days to reach full feed or to reach the point where they would consume all they could eat. The amount which a steer would eat on full feed varied from time to time. Steer 164 reached a maximum daily consumption of 25 pounds of grain while the others ate a maximum of 20 to 22 pounds.

In calculating the digestible nutrients consumed the digestion factors of Steer 48 were used for Steers 48, 121, and 589. This first steer was the only one in the digestion stalls while on full feed. He gave lower digestion coefficients than the animals on scant rations. The digestion factors of Steer 164 on maintenance were so eccentric that it was considered inadvisable to use the factors of Steer 48 for the full feed period. Consequently the factors obtained for Steer 164 when on maintenance were used thruout for this steer.

Figures 18 and 19 show graphically by ten-day periods the consumption of nutrients. The weights of ash and crude fiber are so near the weights of ether extract and crude protein respectively that a separate scale is used for them.

Figure 19 shows a greatly decreased consumption of nutrients for Steer 48 at the same points where its weight falls off (see Figure 17). This steer was very slow in recovering its full appetite and only for a few periods after the first sickness did it ever consume as much feed as before.

TABLE 25.—NUTRIENTS CONSUMED BY STEER 121 DURING GROWTH

Dates 1907	Crude protein lbs.	Crude fat lbs.	Nitrogen free extract lbs.	Crude fiber lbs.	Ash lbs.	Digestible crude protein lbs.	Digestible crude fat lbs.	Digestible N. F. E. lbs.	Digestible crude fiber lbs.
July 11 to July 30.....	32.996	10.242	178.765	37.741	10.292	20.338	7.770	127.992	16.349
July 31 to Aug. 29.....	77.574	20.601	407.810	78.413	22.522	47.816	15.630	291.984	33.969
Aug. 30 to Sept. 28...	109.369	31.029	499.115	73.682	29.308	67.414	23.541	357.353	31.919
Sept. 29 to Oct. 28....	105.889	33.448	518.805	101.116	29.117	65.269	25.376	371.454	43.803
Oct. 29 to Nov. 27....	108.430	33.069	527.983	106.496	30.276	66.835	25.089	378.025	46.134
Nov. 28 to Dec. 10...	42.713	12.995	207.774	41.992	11.885	26.328	9.850	148.762	18.191
Total 153 days.....	476.971	141.384	2340.252	439.440	133.400	294.000	107.265	1675.574	190.365
Daily average	3.117	0.924	15.296	2.982	0.872	1.922	0.701	10.951	1.244

TABLE 26.—NUTRIENTS CONSUMED BY STEER 48 DURING GROWTH

Dates 1907/1909	Crude protein lbs.	Crude fat lbs.	Nitrogen free extract lbs.	Crude fiber lbs.	Ash lbs.	Digestible crude protein lbs.	Digestible crude fat lbs.	Digestible N. F. E. lbs.	Digestible crude fiber lbs.
July 1 to July 30.....	53.200	16.485	287.840	61.200	16.648	32.792	12.507	206.088	26.512
July 31 to Aug. 29.....	86.468	20.531	456.407	85.480	23.413	53.298	15.576	325.778	37.010
Aug. 30 to Sept. 28...	112.894	32.628	515.008	78.254	30.663	69.587	24.754	368.735	33.890
Sept. 29 to Oct. 28...	111.983	35.483	550.029	106.415	30.730	69.024	26.920	393.810	46.099
Oct. 29 to Nov. 27...	81.312	24.447	383.916	80.959	22.691	50.120	18.547	274.876	35.071
Nov. 28 to Dec. 27...	63.024	18.550	294.577	80.069	21.381	38.847	14.058	210.931	34.686
Dec. 28 to Jan. 26....	73.689	27.196	361.730	86.328	22.204	45.421	20.633	258.991	37.397
Jan. 27 to Feb. 25....	74.342	37.506	374.053	85.209	22.460	45.824	28.455	267.814	36.913
Feb. 26 to March 26...	80.302	36.170	400.669	90.334	25.002	49.497	27.441	286.871	39.133
March 27 to April 25...	94.386	16.277	498.620	104.067	28.054	58.179	12.349	357.002	45.082
April 26 to May 25...	87.000	13.150	452.478	102.446	26.878	53.626	9.977	323.965	44.380
May 26 to June 24....	68.712	10.453	363.875	74.586	20.277	42.353	7.930	260.527	32.311
June 25 to July 24....	87.603	17.326	457.650	95.261	26.372	53.998	13.145	327.668	41.267
July 25 to Aug. 23....	95.950	24.450	489.170	101.920	29.632	59.143	18.550	350.236	44.152
Aug. 24 to Sept. 22...	97.843	26.354	511.436	93.738	29.184	60.309	19.994	366.178	40.007
Sept. 23 to Oct. 22...	87.453	23.663	456.880	83.052	26.196	53.905	17.953	327.117	35.978
Oct. 23 to Nov. 21...	85.276	23.092	448.951	80.385	24.499	52.563	17.519	321.440	34.823
Nov. 22 to Dec. 21...	80.933	22.837	424.792	77.327	23.603	49.886	17.326	304.143	33.498
Dec. 22 to Jan. 17....	77.110	23.390	404.500	71.540	21.563	47.530	17.746	289.614	30.991
Total 567 days.....	1599.480	449.968	8132.581	1638.570	471.450	985.903	341.138	5822.765	709.829
Daily average	2.821	0.794	14.343	2.890	0.831	1.739	0.602	10.270	1.252

TABLE 27.—NUTRIENTS CONSUMED BY STEER 164 DURING GROWTH

Dates 1909	Crude protein lbs.	Crude fat lbs.	Nitrogen free extract lbs.	Crude fiber lbs.	Ash lbs.	Digestible crude protein lbs.	Digestible crude fat lbs.	Digestible N. F. E. lbs.	Digestible crude fiber lbs.
May 31 to June 19...	47.681	10.263	242.738	50.938	14.039	29.455	6.607	206.495	15.051
June 20 to July 19...	102.023	24.111	519.714	106.978	29.313	63.026	15.522	442.116	31.609
July 20 to Aug. 18...	113.657	31.203	565.834	117.783	30.596	70.213	20.088	481.349	34.801
Aug. 19 to Sept. 17...	113.988	31.264	567.768	114.446	31.285	70.417	20.127	482.995	33.815
Sept. 18 to Oct. 17...	120.020	33.401	586.252	109.438	31.986	74.144	21.503	498.719	32.336
Oct. 18 to Nov. 7....	93.219	26.450	439.022	76.203	24.151	57.587	17.028	373.472	22.516
Total 161 days	590.588	156.692	2921.328	575.786	161.370	364.842	100.875	2485.145	170.127
Daily average	3.668	0.973	18.145	3.576	1.002	2.266	0.627	15.436	1.057

TABLE 28.—NUTRIENTS CONSUMED BY STEER 589 DURING GROWTH

Dates 1909	Crude protein lbs.	Crude fat lbs.	Nitrogen free extract lbs.	Crude fiber lbs.	Ash lbs.	Digestible crude protein lbs.	Digestible crude fat lbs.	Digestible N. F. E. lbs.	Digestible crude fiber lbs.
Aug. 29 to Sept. 17...	42.606	11.373	208.778	46.935	12.189	26.262	8.628	149.481	20.332
Sept. 18 to Oct. 17...	93.868	25.673	446.385	95.521	25.282	57.859	19.478	319.603	41.380
Oct. 18 to Nov. 16...	97.752	27.551	456.440	82.215	25.727	60.253	20.902	326.802	35.616
Nov. 17 to Dec. 19...	112.183	31.390	526.701	94.205	29.642	69.148	23.815	377.107	40.810
Total 113 days.....	346.409	95.987	1638.304	318.877	260.103	213.523	72.823	1172.993	138.138
Daily average.....	3.066	0.849	14.498	2.822	2.302	1.890	0.644	10.380	1.222

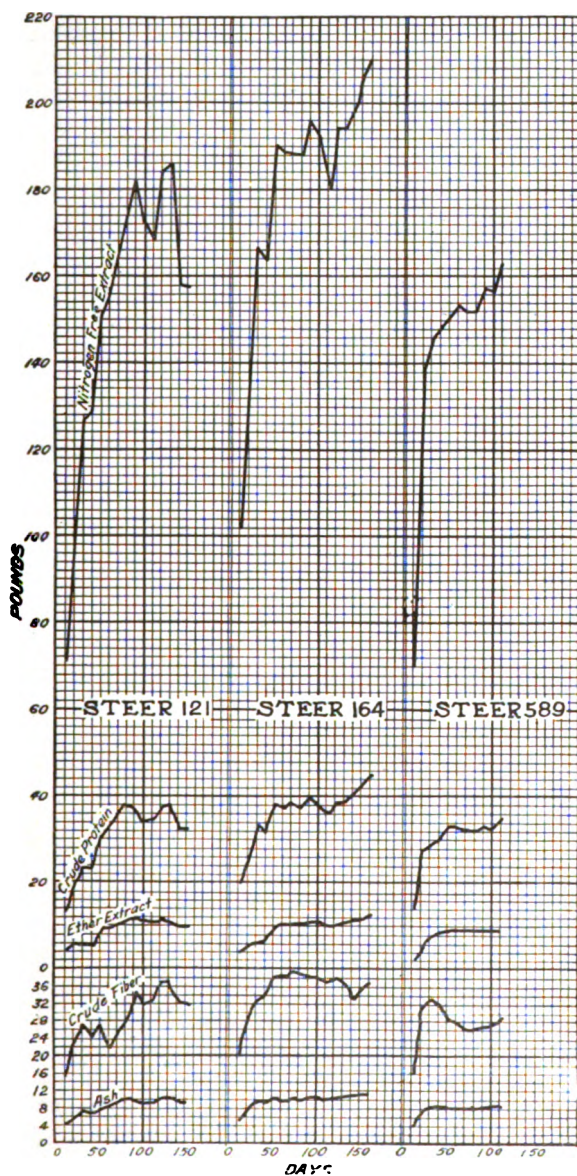


Fig. 18.—Nutrients consumed by Steers 121, 164, and 589 during growth. By ten-day periods

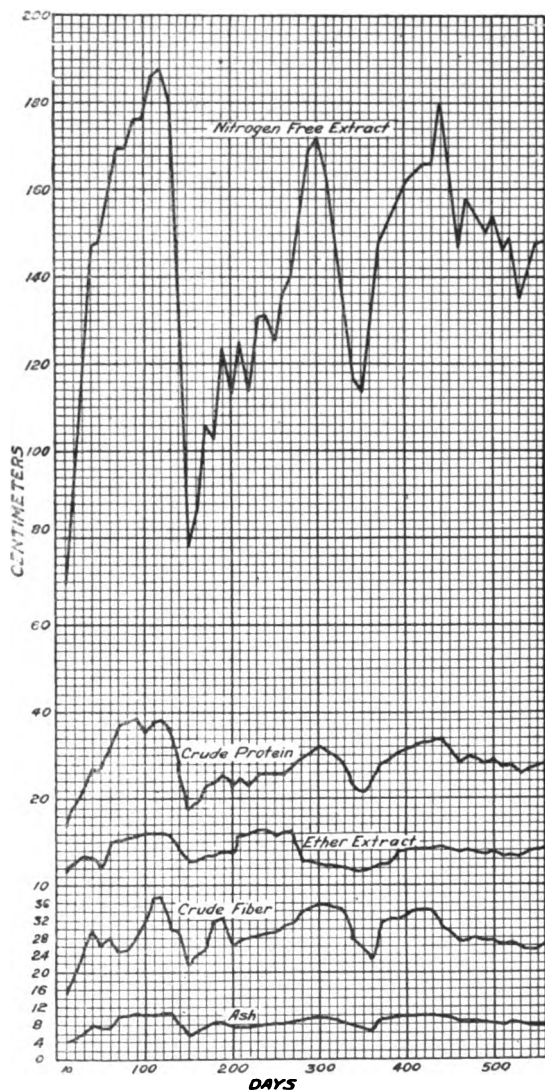


Fig. 19.—Nutrients consumed by Steer 48 during growth. By ten-day periods

GROSS COST OF GAIN IN WEIGHT

In order to study the gross cost of each pound of gain made by these animals the data are assembled in Table 29. For Steer 48 the data are given for the first 120 days and for the total 567 days

of feeding. This affords an opportunity of studying this animal's gains before sickness showed its effect. The grain and hay consumption is shown in addition to the organic nutrients and the energy. The methods of calculation have already been described.

The first three animals shown and Steer 48, at the end of the first 120 days, were all in about the same condition, namely, between 30 and 60 days under prime condition. Therefore this data can all be studied together. Steer 164, the ridgeling, made the most rapid gains, almost four pounds daily. The other animals all gained about 3.25 pounds daily.

In amount of feed consumed per pound of gain, Steers 164 and 589 were somewhat more economical than the other two. They needed 5.39 pounds of grain and 2.14 pounds of hay, and 5.24 pounds of grain and 2.21 pounds of hay respectively. The others needed about 5.6 pounds of grain and 2.2 pounds of hay per pound of gain.

TABLE 29.—GROSS COST PER POUND OF GAIN

Steer	121	164	589	48	48
Length of periods, days	153	161	113	120	567
Weight at beginning, pounds	764.2	921.0	1031.3	841.5	841.5
Weight at end, pounds	1266.4	1552.8	1405.5	1231.0	1805.0
Weight gained, pounds	502.20	631.70	374.20	389.50	963.50
Average daily gain, pounds	3.28	3.92	3.31	3.25	1.70
Total grain eaten, pounds	2806.25	3403.43	1960.87	2172.00	9602.06
Total hay eaten, pounds	1103.25	1349.77	827.04	842.50	3972.66
Average daily grain, pounds	18.34	22.54	17.35	18.10	16.93
Average daily hay, pounds	7.21	8.88	7.32	7.02	7.01
Grain per pound of gain, pounds	5.59	5.39	5.24	5.58	9.97
Hay per pound of gain, pounds	2.20	2.14	2.21	2.16	4.12
Total organic nutrients eaten, pounds	3398.05	4244.39	2399.58	2610.31	11820.60
Digestible organic nutrients eaten, pounds	2267.20	3120.99	1597.4	1734.0	7859.64
Metabolizable energy consumed, therms	3899.59	5368.10	2747.66	3998.65	13518.57
Total organic nutrients per pound of gain, lbs.	6.77	6.72	6.41	6.70	12.27
Digestible organic nutrients per pound of gain, lbs.	4.51	4.9	4.2	4.48	8.16
Metabolizable energy per pound of gain, therms	7.77	8.56	7.34	7.70	14.03

The later gains of Steer 48 were slower and more costly. Throughout the entire period this animal averaged 1.7 pounds of gain daily at a cost of 9.97 pounds of grain and 4.12 pounds of hay. This was about 80 per cent more costly than the gains on animals which fattened more quickly. Since the rate of gain was slower the maintenance cost played a larger part in the gross cost of the gain. Then there were the periods of sickness and loss in weight. Finally there was the naturally greater cost of the gain necessary to make the animal excessively fat.

In terms of total organic nutrients consumed the relative order of cost for the animals is not the same as that shown by the grain and hay needed per pound of gain. This is because the dates covered by the full feed periods were not the same and so the samples of grain and hay were different. The feed consumed by Steer 164 and Steer 589 was richer in nutrients than that consumed by Steer 121. Steer 589 needed 6.41 pounds of organic nutrients per pound of gain. Steer 121, Steer 164, and Steer 48 for 120 days needed 6.7 to 6.77 pounds. For the full period of 567 days Steer 48 consumed 12.27 pounds of organic nutrients per pound of gain.

In terms of the metabolizable energy cost of a pound of gain Steer 589 which required 7.34 therms was the most economical feeder. Steer 121 and Steer 48 for 120 days required a cost of 7.77 and 7.70 therms respectively. On account of the higher digestion coefficients Steer 164 was charged with more digestible nutrients and consequently required a cost of 8.50 therms. For the full 567 days Steer 48 required 14.03 therms of energy per pound.

NET COST OF GAIN IN WEIGHT

The net cost of the weight gained by these animals is found by subtracting the maintenance cost from the gross consumption and dividing this productive consumption by the weight gained. In calculating the average daily maintenance cost during the full feed period, the average daily consumption during the maintenance period was multiplied by the five-ninths power of the ratio of the average weight while the animals were on full feed, to the average weight while they were on maintenance. This is based on the relation of body surface to body weight.⁸ The surfaces of steers are proportional to the five-ninths power of the weights for fat steers and to the five-eighths power for medium and thin steers. The total maintenance cost while the animals were on full feed was found by multiplying the average daily cost by the number of days they were on full feed. This quantity was subtracted from the gross consumption to give the productive consumption. This divided by the weight gained gave the cost of the weight gained in terms of productive feed or energy.

According to the theory advanced in the foregoing paragraph the cost of maintenance for the thin animals, Steer 121 and Steer 48, should be proportional to the five-eighths power of the weights until they could be classed as fat and after that the five-ninths power should be used. A calculation was made by using the extreme case of the five-eighths power entirely. This made a difference of 0.25

per cent of the net energy cost of a pound of gain for Steer 18 and 1.5 per cent for Steer 48 thruout the entire period. The true value would lie between the one given in Table 30 and a value smaller by the amount just shown. Therefore the error could hardly be more than one-half that shown, or about 0.75 per cent of the total amount for Steer 48. The error in the calculation of the per cent of available energy would be about double this error. The small size of the error involved makes it inadvisable to use a more complex method of calculation than that explained in the preceding paragraph.

TABLE 30.—NET COST PER POUND OF GAIN

Steer	121	164	589	48	48
Length of period, days	153	161	113	120	567
Weight at beginning, pounds	764.2	921.0	1031.3	841.5	841.5
Weight at end, pounds	1266.4	1552.8	1405.5	1231.0	1805.0
Weight gained, pounds	502.20	631.70	374.20	389.50	963.50
Average weight of animal, pounds	1041.10	1258.80	1249.10	1039.50	1384.30
Productive grain consumed, pounds	1671.90	2175.76	1219.27	1237.71	4491.79
Productive hay consumed, pounds	605.70	881.39	529.12	435.43	1746.14
Productive grain eaten daily, pounds	10.93	13.51	10.79	10.31	7.92
Productive hay eaten daily, pounds	3.96	5.47	4.68	3.63	3.08
Productive grain per pound of gain, pounds....	3.33	3.44	3.26	3.18	4.66
Productive hay per pound of gain, pounds.....	1.21	1.40	1.41	1.12	1.81
Productive organic nutrients eaten, pounds.....	1996.62	2747.87	1491.49	1459.92	5447.33
Productive digestible organic nutrients, pounds	1162.64	2018.22	847.42	836.10	2833.14
Productive energy consumed, therms	1999.79	3471.37	1457.56	1438.12	4873.10
Productive organic nutrients per pound of gain	3.98	4.35	3.99	3.75	5.65
Productive digestible organic nutrients					
per pound gain	2.32	3.19	2.26	2.15	2.94
Productive energy per pound of gain, therms..	3.98	5.50	3.89	3.69	5.06

Table 30 gives the results of the calculations indicated. This table shows that in terms of productive grain and hay, productive nutrients, or productive energy, Steer 48 for the first 120 days of full feed was the most economical animal. However, for the entire full feed period even after the maintenance cost had been subtracted the steer showed a much higher cost of weight gained. The increase was about 50 per cent over the first 120 days and about 40 per cent over Steer 121 and Steer 589.

Steer 164 gave a greater net cost of gain than the other animals on short feed. In terms of digestible nutrients and energy the cost was even greater. This was due to the higher digestion coefficients credited to Steer 164.

By averaging the values for Steer 121, Steer 589, and Steer 48 for 120 days, it was found that 3.32 pounds of grain and 1.25 pounds

of hay above the cost of maintenance were necessary to produce each pound of gain up to the time when the animals lacked 40 to 50 days of being finished. The average cost in terms of total organic nutrients above maintenance was 3.91 pounds. In terms of digestible organic nutrients the cost was 2.24 pounds above maintenance. The energy required to produce a pound of gain was 3.85 therms above maintenance.

GROWTH DURING FATTENING

The growth made by these animals while on maintenance has already been discussed. Tables 20 to 24 give the measurements taken after the animals were put upon full feed as well as the maintenance measurements. There is but one set of measurements on record for Steer 121. Consequently only the other three animals can be discussed here. Steer 589 was about two years and eleven months old at the beginning of full feed, Steer 164 was three years and two months, and Steer 48 was three years and four months.

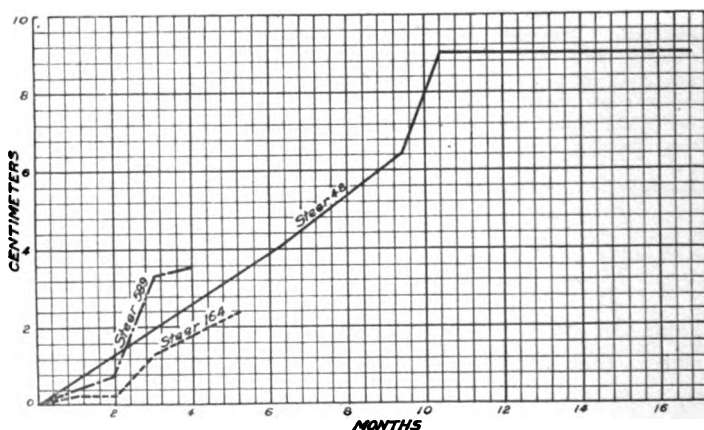


Fig. 20.—Changes in height at withers during growth

Gain in height at withers.—Figure 20 shows graphically the gain in height at the withers while the steers were fattening. The apparent steadiness of gain made by Steer 48 was due to the great length of time between measurements. Six months had elapsed between the first and second measurements and three months between the second and third. At the end of four months the animals averaged about a three-centimeter gain in height. Shortly after ten months on full feed, Steer 48 reached its maximum gain of nine centimeters and gained no more during the ensuing six and one-half

months. Figure 9 shows that Steer 164 had stopped growing before the end of its maintenance period. Consequently the gain shown in Plate IV may be flesh rather than skeletal gain.

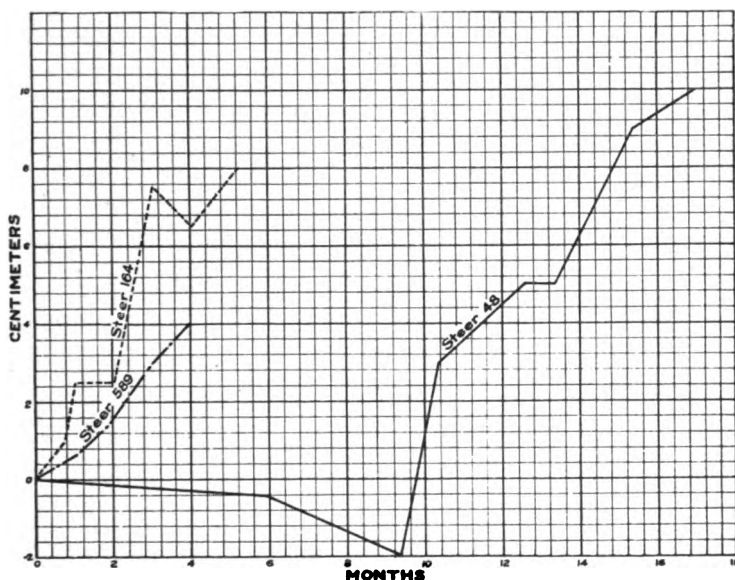


Fig. 21.—Changes in length from shoulder to hips during growth

Gain in length, shoulder to hips.—Figure 21 shows the gain in length from shoulder to hips. Steer 48 apparently lost two centimeters during nine months. How much of that was due to errors in this measurement could not be determined. But the animal probably did not lose in length. Steer 589 gained four centimeters in four months and Steer 164, eight centimeters in a little over five months. This shows more rapid gain in length on full feed than on maintenance. The men in charge of the experiment at that time judged that Steer 164 had ceased to grow before the end of maintenance, and the slight change in height seemed to corroborate this opinion. In spite of this, note the great gain in length. This steer had, however, shown eccentricities in this measurement during the maintenance period. At one time it showed a gain of four centimeters but it finished with a net gain of only one and one-half centimeters. Had the gain remained four centimeters, this animal would still have shown a gain of five and one-half centimeters in about five months. Steer 48 finally gained in length and finished with a gain of ten centimeters in about a year and a half. This certainly

indicates growth in skeleton. If the bone itself did not grow there must have been sufficient thickening of the cartilage between the bones to cause this lengthening, which of course was skeletal growth.

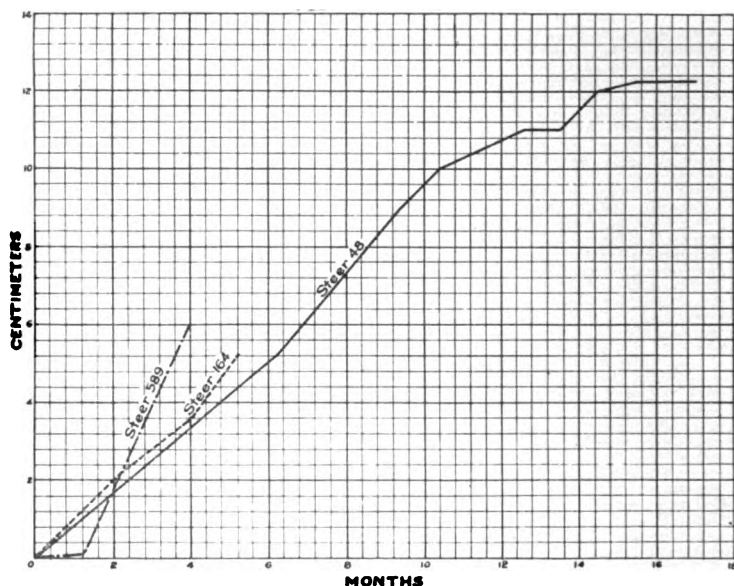


Fig. 22.—Changes in width of hips during growth

Gain in width of hips.—The gain in width of hips is an excellent measure of skeletal growth during maintenance. During fattening, however, it is affected by the gain in flesh and may represent little, if any, growth of skeleton. Rather rapid gains, four to six centimeters in four to five months, are shown in Figure 22. Steer 48 continued to grow in width of hips until in about 14 months it had gained twelve centimeters. During the following three months very little change was made.

Gain in heart girth.—Figure 23 shows the gains made in the circumference of the body at the region of the heart. This measurement for very young steers may show skeletal growth, but for steers more than one year old it is a measure of the flesh or fatness of the animal. During maintenance the animals all lost in circumference at this place. The three steers made very rapid gains during fattening. Steer 164 added 36 centimeters to this measurement in a little over five months. The other animals did not gain quite so rapidly. After the first nine months Steer 48 gained more slowly. His total gain was 46.5 centimeters in about 17 months.

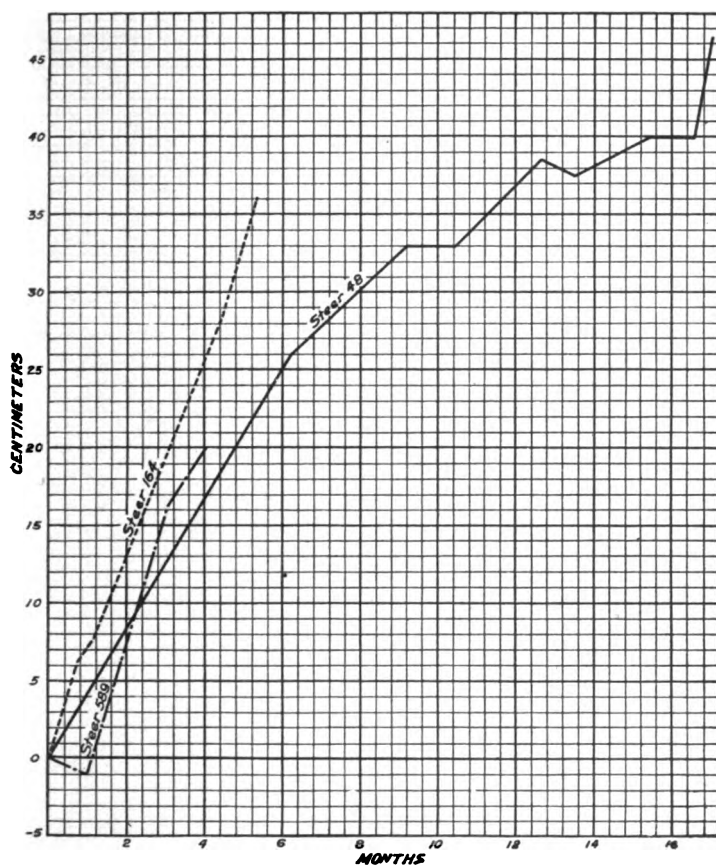


Fig. 23.—Changes in girth at heart during growth

Gain in paunch girth.—Figure 24 shows the gains in circumference at the region of the paunch. This measurement was partly a measure of the “fill” of the animals and partly of the fat laid on around the intestines and stomach. Steer 164 gained about 75 centimeters in a little more than five months. Steer 589, which was fatter than Steer 164 in the beginning, made only about half as much gain in four months. Steer 48 added 54 centimeters to this measurement in about seventeen months.

Changes in cross sections.—The changes in cross section of the animals on full feed are shown in Figures 14, 15 and 16. The animals all rounded out in body and increased in the area of cross section. The change from angularity to rotundity was especially striking in Steers 164 and 589.

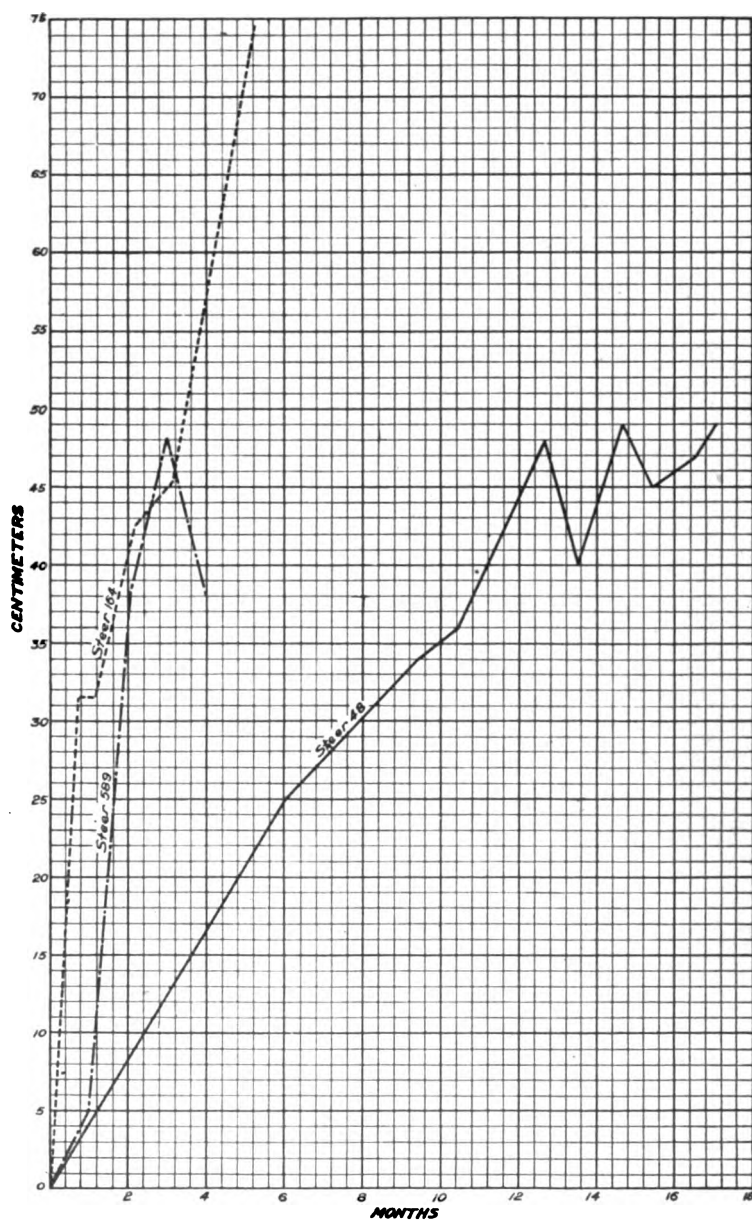


Fig. 24.—Changes in girth at paunch during growth

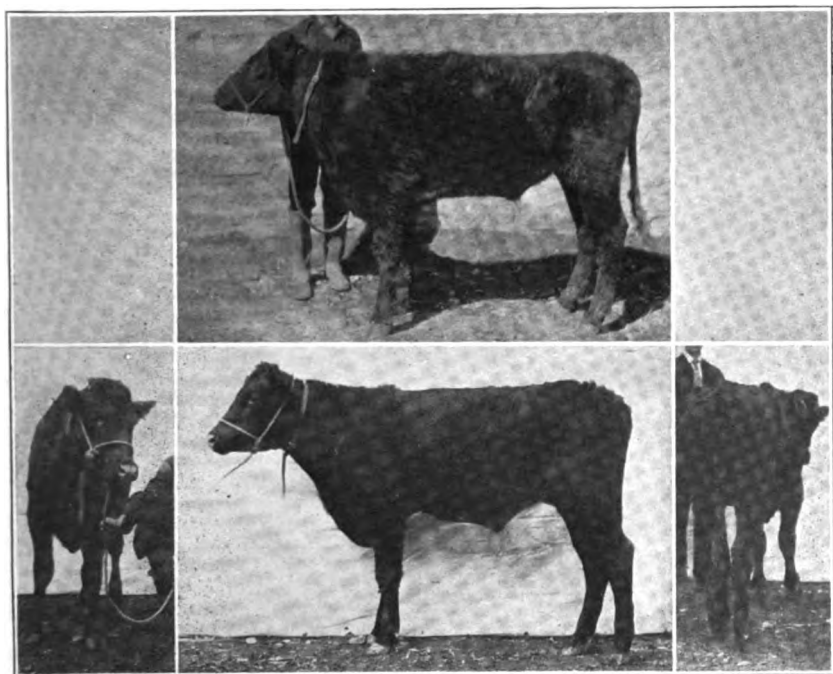


PLATE I.—Steer 18 at beginning and end of maintenance

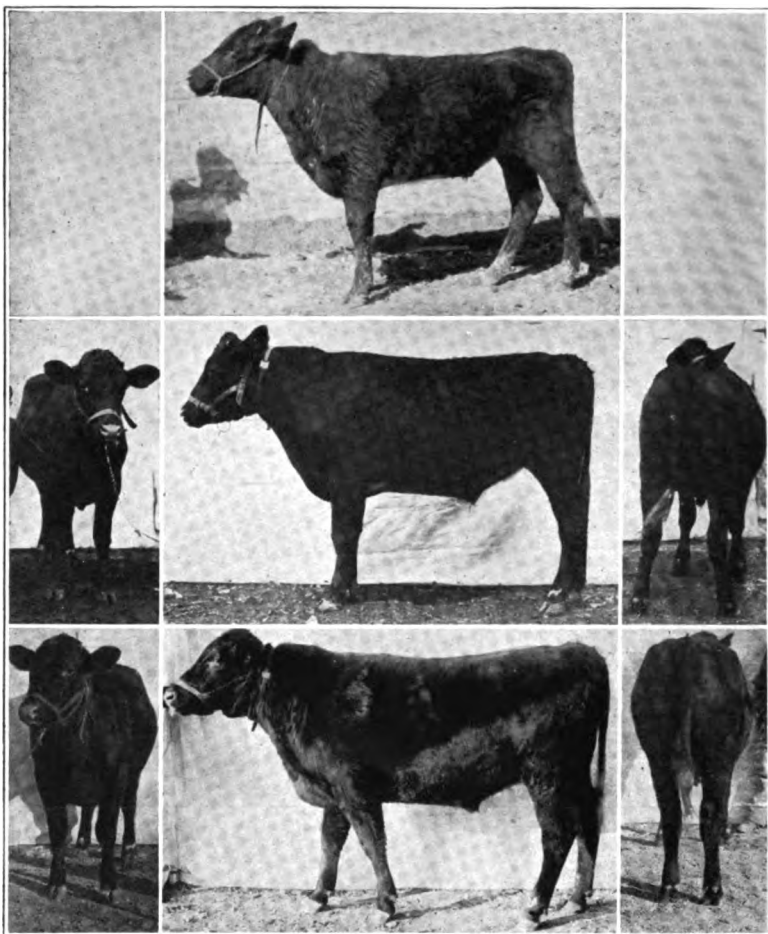


PLATE II.—Steer 121 at beginning and end of maintenance, and at the end of the full-fed period

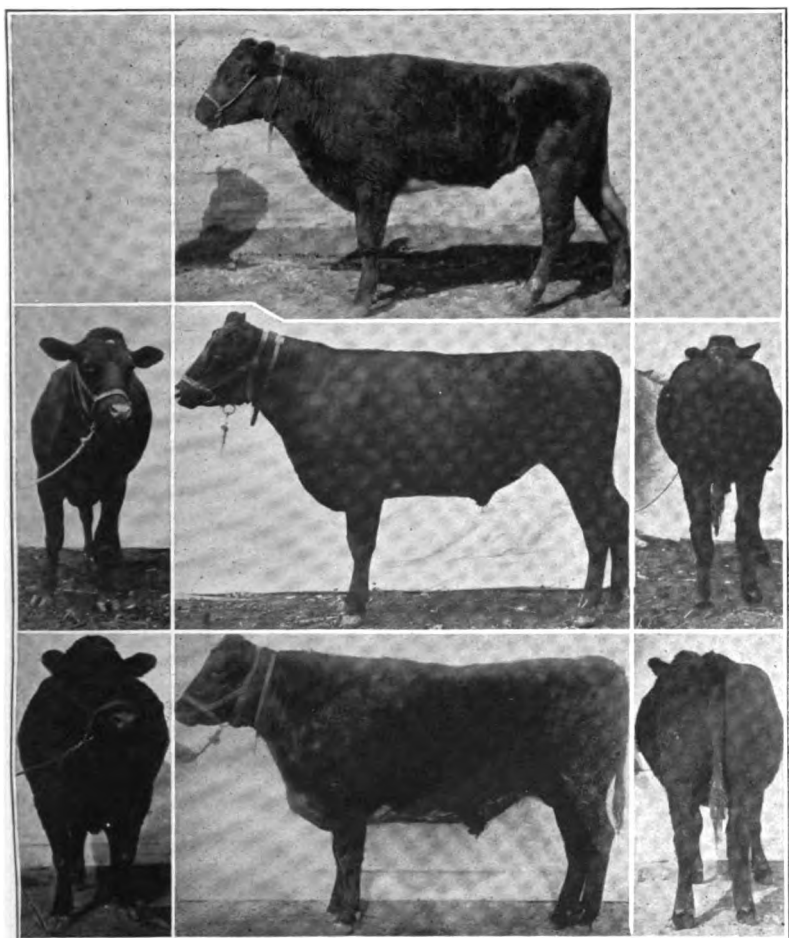


PLATE III.—Steer 48 at beginning and end of maintenance, and at the end of the full-fed period

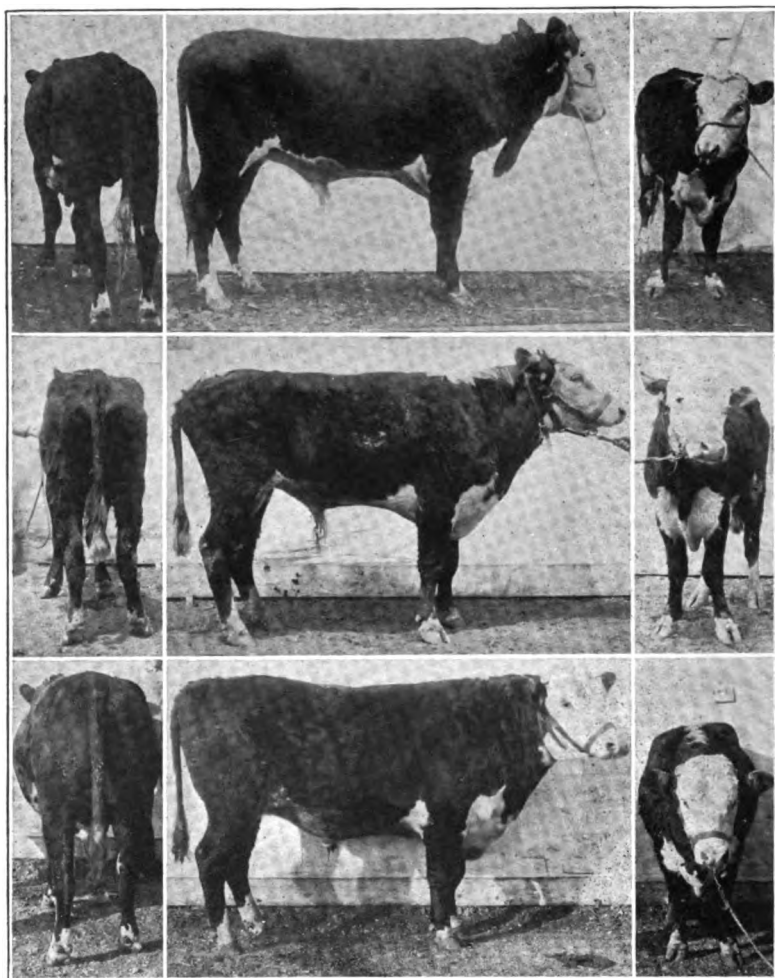


PLATE IV.—Steer 164 at beginning and end of maintenance, and at the end of the full-fed period



PLATE V.—Steer 197 at beginning and end of maintenance

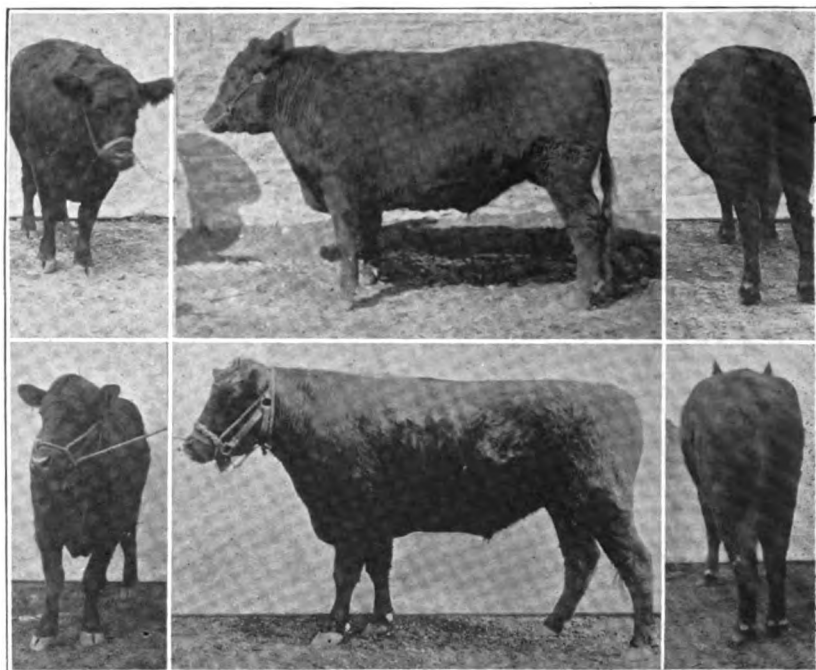


PLATE VI.—Steer 588 at beginning and end of maintenance

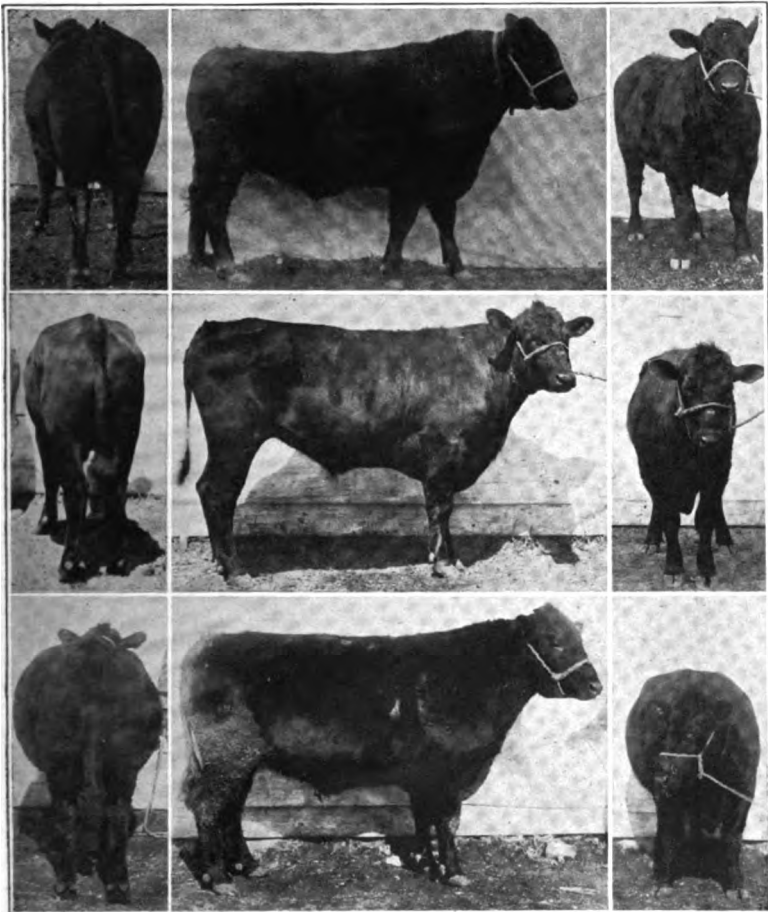


PLATE VII.—Steer 589 at beginning and end of maintenance, and at the end of the full-fed period

Photographs of animals.—Plates II, III, IV and VII show the photographs of the animals at the beginning and end of full feed. The top groups of photographs are of the animals at the beginning of maintenance. It will be seen that steers 164 and 589 again made the most striking changes in appearance after fattening.

SLAUGHTER HOUSE DATA AND RESULTS

PROPORTIONS OF OFFAL PARTS, CARCASS PARTS, LEAN AND FAT TISSUE, AND BONE

Each animal was slaughtered on the day following the closing of its respective feeding period. Table 1 gives the dates of slaughter. On the morning of slaughter the animal was fed and weighed as usual but no water was given. If slaughter occurred late in the morning or in the afternoon the animal was weighed again just before slaughtering. The slaughter house is a two-story frame building with a smooth concrete floor. It is supplied with a drain, steam, water, electricity for light and power, stoves for heating, a windlass and pulley with a strong rope for hoisting the animal, an overhead track for hanging the carcass, a fairly complete set of slaughtering and butchering tools, and grinding machinery.

The animal was killed or stunned with a killing hammer and then hoisted by the hind feet and bled as completely as possible. This was assisted by pumping the fore legs. The blood was caught in a tared pan and weighed. The volume of this main weighed portion was determined. A tared pan was kept under the animal to catch any blood that might drip from the carcass. Samples of blood caught in a beaker were rapidly poured out into tared containers and crucibles for the analysis. The blood was still warm and no clotting had occurred.

The carcass was then lowered and the dressing was continued. The viscera and contents were caught in two large tared tubs and weighed. They were then separated, cleaned, freed from fatty tissue and weighed again. The stomachs were cleaned by washing with water and drying with cloths. Some water was absorbed during this process since the organ usually weighed a bit more after this washing than it did when it was cleaned by removing the contents with the hand as thoroly as possible. The intestines were cleaned by simply stripping them thru the fingers. The contents of the stomachs, intestines, and urinary bladder were determined by difference.

TABLE 31.—SLAUGHTER HOUSE WEIGHTS OF OFFAL PARTS

Steer	18	121	48	197	164	588	589
	grams	grams	grams	grams	grams	grams	grams
Live weight, lbs.	755.5	1255.5	1785.0	1063.8	1506.8	1229.2	1394.8
Live weight.....	342,687	569,469	809,645	482,547	683,451	557,535	632,672
Warm empty weight	302,183	508,513	744,708	444,750	608,656	485,754	564,913
Blood	15,599	24,433	25,634	20,067	29,126	21,331	25,579
Hide and hair	25,674	29,564	41,164	35,209	46,266	38,188	45,681
Heart, pericardium, arteries....	2,594	4,273	6,780	3,806	5,453	5,099	4,665
Heart, marketable	1,496	2,128	2,573	1,687	2,715	2,162	2,180
Heart, lean	1	1,596	1,700	1,439	1	1,760	1
Lungs and trachea	3,079	4,631	10,970	3,879	4,794	3,277	5,555
Brain	417	426	445	417	398	441	466
Spinal cord	305	284	329	262	488	391	223
Tongue, total including bones	2,664	3,345	4,333	3,569	4,081	3,135	4,021
Tongue bone and larynx.....	243	298	514	528	548	416	531
Tongue, marketable	1,491	1,115	2,376	1,719	1,859	1,920	1,744
Gullet	772	780	863	976	1,004	706	823
Stomachs	7,645	14,253	14,113	8,838	17,132	9,938	13,201
Intestines	6,099	9,967	7,090	5,963	9,743	6,439	8,104
Intestines, length, cm.....	1	1	5,619	4,237	1	4,393	3,002
Heart sweetbread	1	1	741	179	520	331	606
Neck sweetbread	1	691	428	225	414	234	626
Spleen	489	922	1,020	997	909	1,071	1,246
Pancreas	247	419	297	334	733	525	608
Liver	2,625	7,035	8,166	3,763	8,070	3,551	6,409
Gall bladder and gall	93	485	576	321	327	320	208
Urinary bladder	124	149	261	269	176	177	123
Testicle					194		
Penis	199	176	319	452	893	396	393
Diaphragm	347	751	1,021	855	923	527	945
Kidney, right	367	549	1,227	391	564	574	473
Kidney, left	395	1	1	391	1	1	472
Stomach fat	3,307	17,595	15,648	2,665	6,527	3,229	5,697
Intestinal fat	2,393	9,781	28,735	3,853	8,486	6,158	12,168
Caul fat	1	1	17,454	4,510	8,519	4,523	4,629
Horn, right	140	none	none	65 ¹	none	none	none
Teeth, right	341	278	356	377	1	1	1
Hoofs, right	533	584	712	779	1	1	1
Dew claws, right	1	156	126	115	119	144	1
Dew claws, left	1	1	125	114	118	143	1
Right fore foot and hoof.....	1,823	2,013	2,246	2,166	2,064	2,060	2,031
Right hind foot and hoof.....	1,873	2,036	2,273	2,138	2,002	2,000	2,024
Left fore foot and hoof.....	1	1	2,238	2,110	2,002	2,074	2,164
Left hind foot and hoof.....	1,829	2,015	2,308	2,082	2,069	2,016	1,972
Forequarter, right	53,977	93,440	135,581	82,240	107,581	91,398	110,167
Hindquarter, right, including kidney and fat	47,411	79,492	123,816	72,117	99,066	76,423	87,114
Left half carcass, including kidney and fat	100,917	176,230	266,019	156,029	1	1	198,173

¹These parts were not separated.²Dew claws of this animal were included with the horn.³These were included with hide.⁴These parts were not weighed.⁵The intestines were not measured.⁶Both kidneys were weighed together.

TABLE 32.—SLAUGHTER HOUSE WEIGHTS OF CARCASS PARTS

Steer	18	121	48	197
	grams	grams	grams	grams
Head, total	10,472	12,423	13,451	11,273
Lean, total	2,968	3,120	2,998	2,670
Fat, total	436	1,106	1,338	914
Bone, total	7,068	8,197	8,865	7,361
Shin, right	5,216	7,709	7,973	7,840
Lean, right	2,340	4,022	3,989	4,041
Fat, right	435	1,011	954	890
Bone, right	2,382	2,632	3,004	2,894
Neck, right	1,588	1,806	2,418	2,046
Lean, right	1,143	981	1,250	1,281
Fat, right	none	395	736	247
Bone, right	390	427	429	515
Chuck, right	26,648	39,635	59,420	38,514
Lean, right	19,029	24,884	34,956	25,945
Fat, right	1,832	8,468	16,534	5,526
Bone, right	5,611	5,980	7,642	6,967
Plate, right	11,113	26,767	36,423	20,041
Lean, right	5,884	14,425	13,845	9,339
Fat, right	2,621	9,174	19,031	7,652
Bone, right	2,490	3,071	3,428	2,938
Rib, right	9,412	17,372	29,349	13,794
Lean, right	6,169	10,620	12,125	8,078
Fat, right	711	3,729	13,505	2,927
Bone, right	2,356	2,980	3,647	2,756
Loin, right	16,556	30,731	48,003	25,474
Lean, right	11,345	16,843	21,577	15,331
Fat, right	2,231	10,229	21,913	6,219
Bone, right	2,826	3,417	4,684	3,747
Flank, right	2,447	4,355	12,746	5,286
Lean, right	1,397	2,015	3,374	2,013
Fat, right	1,003	2,317	9,353	3,215
Bone, right	47	17	40	56
Rump, right	3,515	5,963	9,809	5,853
Lean, right	1,804	2,667	3,544	2,439
Fat, right	668	1,962	4,499	1,806
Bone, right	952	1,325	1,760	1,582
Round, right	19,278	29,411	38,244	28,576
Lean, right	15,242	21,224	25,142	19,976
Fat, right	1,415	5,000	9,760	5,055
Bone, right	2,543	2,700	3,159	3,027
Shank, right	4,026	4,701	5,779	5,352
Lean, right	1,242	1,320	1,785	1,873
Fat, right	224	636	720	577
Bone, right	2,483	2,718	3,262	2,926
Tail right	342	372	414	518
Lean right	110	127	95	183
Fat, right	none	29	36	60
Bone, right	232	216	283	275
Kidney, fat, right	1,222	3,636	8,585	1,151

TABLE 33.—SLAUGHTER HOUSE WEIGHTS OF CARCASS PARTS

Steer	164	588	589
	grams	grams	grams
Head, total, including teeth	13,480	13,865	12,800
Shin, right	7,201	6,123	9,978
Neck, right	1,890	1,361	2,359
Chuck, right	53,687	45,359	45,667
Plate, right	25,256	22,226	29,030
Rib, right	19,450	16,329	23,133
Loin, right	35,552	30,617	31,504
Flank, right	9,135	6,350	8,340
Rump, right	8,333	8,391	5,374
Round, right	34,446	29,257	30,060
Shank, right	5,350	with round	4,680
Kidney fat, right	2,965	1,434	6,684
Tail, total	1,042	855	756

The weights and measurements taken are given in Table 31. Few of the weights need explanation. The warm empty weight was obtained by subtracting the contents of the stomachs, intestines, and urinary bladder from the live weight at slaughtering. The heart and neck sweetbreads are the thymus gland. The stomach and intestinal fats are those which adhered to the respective organs. The intestinal fat is largely included in the mesentery. The caul fat is that laid on in the part of the peritoneum stretching like an apron over the stomachs and intestines. The different divisions are mutually exclusive excepting where specified otherwise.

The weather was generally cold enough to chill the carcasses in the slaughterhouse where they were hung for two days. The right half was then divided into wholesale cuts as practiced by the Kansas City packers. The weights were recorded and each cut separated carefully into lean meat, fatty tissue, and bone (including the coarser ligaments and cartilage). Care was always taken not to get any lean meat in with the fat. The weights of the carcasses and quarters of the animal are given in Table 31. Table 32 gives the wholesale cuts and their separation for the four animals that were later analyzed. Table 33 gives the weights of the wholesale cuts for the three animals that were not analyzed. The weights for the head and tail are given in these last two tables altho they do not form a part of the carcass proper. On account of the difficulty of splitting the head evenly the weights are given for the entire head.

The left half of the carcass was used for photographs of the cuts of meat, water color drawings, and cooperative cooking experiments.

PROPORTION OF OFFAL PARTS

Table 34 shows the proportion of carcass and offal parts to the weight of the animal. The animals are arranged in the order of increasing fatness. The warm empty weight was taken as the basis of reference for this work. The data has been worked out for a much larger number of animals than is shown here and better results have been attained when the fill has been eliminated.

TABLE 34.—PROPORTION OF CARCASS AND OFFAL PARTS TO EMPTY WEIGHT

Steer	18	197	588	121	589	164	48
Age.	3 yr.	3 yr. 2 mo.	5 yr. 6½ mo.	3 yr.	3 yr. 3¼ mo.	3 yr. 7 mo.	5 yr.
Live weight, grams	342,687	482,547	557,535	569,469	632,672	683,451	809,645
Warm empty weight, grams....	302,183	444,750	485,754	508,513	564,913	608,656	744,708
Per cent empty weight							
to live weight.....	88.180	92.167	87.125	89.296	89.290	89.056	91.980
Per cent carcass to live weight	59.035	64.322	60.200	61.314	62.505	60.473	64.895
Per cent carcass to empty weight	66.948	69.789	69.096	68.663	70.003	67.905	70.553
Per cent carcass and offal fat							
to live weight	60.698	66.608	62.695	66.121	66.061	63.917	72.532
Per cent carcass and offal fat							
to empty weight	68.834	72.268	71.960	74.047	73.984	71.771	78.857
Per cent offal fat to empty							
weight	1.886	2.480	2.864	5.386	3.982	3.866	8.304
Per cent hide and hair							
to empty weight	8.496	7.917	7.862	5.814	8.086	7.601	5.528
Per cent blood to empty weight	5.162	4.512	4.391	4.805	4.528	4.785	3.442
Per cent heart marketable							
to empty weight	0.495	0.379	0.445	0.418	0.386	0.446	0.345
Per cent lungs and trachea							
to empty weight	1.019	0.872	0.675	0.911	0.983	0.788	1.473
Per cent brain and spinal cord							
to empty weight	0.239	0.153	0.171	0.140	0.122	0.146	0.104
Per cent stomachs							
to empty weight	2.530	1.987	2.046	2.803	2.337	2.815	1.895
Per cent intestines to							
empty weight	2.018	1.341	1.326	1.960	1.435	1.601	0.952
Per cent liver to empty weight	0.869	0.846	0.731	1.383	1.135	1.326	1.097
Per cent gall bladder and gall							
to empty weight	0.031	0.072	0.066	0.095	0.037	0.054	0.077
Per cent kidney to empty							
weight	0.252	0.176	0.154	0.216	0.167	0.185	0.165
Per cent spleen to empty							
weight	0.162	0.224	0.221	0.181	0.221	0.149	0.137
Per cent pancreas to empty							
weight	0.082	0.077	0.108	0.082	0.108	0.120	0.040

The proportion of warm empty weight to live weight varied from 87 to 92 per cent. This last value was found for one of the cattle slaughtered after a long maintenance period. This does not seem to be a typical result. The two other maintenance cattle showed pro-

portionally less empty weight and more fill than the partly fat cattle, and these in turn showed less empty weight than the very fat steer. Altho it received a much heavier ration, the fatter animal which was relatively much larger, showed a smaller per cent of fill.

About the same relation was shown in the per cent of carcass to live weight and the per cent of carcass to empty weight. In the latter case the differences were smaller and were even negligible in case of five out of the seven animals. The per cent of carcass plus offal fat gave greater differences, since the fatter steers yielded much more offal fat. The weight of carcass and offal fat of the very fat steer constituted about 79 per cent of the empty weight, while that of the thinnest steer constituted only about 69 per cent. The offal fat is a good indication of the fatness of the steer. The offal fat of the thinnest animal constituted less than 2 per cent of the empty weight, while the offal fat of the fattest steer was more than 8 per cent of its empty weight. Both Steer 589 and Steer 164 were not, in this respect, as fat as Steer 121.

The proportion of hide and hair to empty weight is affected by several conditions. The hide of Angus cattle is thicker and the hair is heavier than that of Hereford or Shorthorn cattle. Thin cattle kept on a low plane of nutrition for a long time develop a heavy growth of hair and a thickening of the hide as a protection against loss of heat. Steer 18, which was very thin illustrated this condition since it had the largest per cent of hair and hide.

The thinnest animal had the greatest per cent of blood and the fattest had the least. The other five animals had about the same per cent altho the three half-fat cattle averaged a few tenths of a per cent above the two maintenance cattle. The ratio of the weight of heart to the empty weight gave a similar result with more individual variations.

The lungs of Steer 48 were excessively heavy. They weighed nearly eleven kilos. Only two animals out of more than sixty on which data have been collected had lungs weighing more than five kilos. Of these, the lungs of Steer 589 were heaviest and weighed 5,555 grams. The lungs of Steer 48 were not much larger in volume than those of the other animals. At the time of slaughter a careful inspection revealed no tubercles in the lungs and consequently the animal was judged free of tuberculosis. However, the point of one lobe of the lungs had grown fast to the wall of the pelvic cavity near the diaphragm. A small abscess (200 grams) was found near the reticulum which evidently had been caused by a nail found embedded

in it. From the foregoing data concerning the weights of the lungs it must, nevertheless be concluded that Steer 48 was abnormal in this respect. It had the highest proportion, about 1.5 per cent, of lungs and trachea to empty weight. The weight of lungs in the very thin steer was a little over one per cent of the empty weight and that of the other animals was even less. The lungs of Steer 588, the fat animal on long maintenance, were the lightest in proportion to the empty weight.

The weight of the brain and spinal cord bore little relation to the weight of the animal. The brain of the thinnest animal constituted 0.239 per cent and that of the fattest 0.104 per cent of the total weight. Between these extremes the values follow the changing weight with some striking individual variations.

The weight of the four stomachs increased with the weight of the animal, but two were not quite typical. The stomach of Steer 121 was proportionally higher in weight and that of Steer 48 was lower. The stomachs of the heavier, fatter steers averaged a greater per cent of the weight than those of the lighter, thinner steers.

The liver, gall bladder and gall, kidneys, spleen, and pancreas increased in weight as the weight of the animal increased. The liver, gall bladder and gall were a somewhat greater proportion of the empty weight in the case of the large heavily fed animals than in the case of the maintenance animals. There were some variations due to individuality, however. The kidneys and spleen were a smaller part of the heavier animals. The pancreas of the full-fed animals was larger in proportion, but that of Steer 48 was a lower per cent of its empty weight. It is difficult to separate the pancreas from the intestinal fat in the very fat animals and this might have accounted for the low weight and per cent of pancreas in Steer 48.

In general, the proportion of empty animal, carcass, and offal fat was greater as the steer became fatter and heavier. The proportion of hide and blood decreased. The organs themselves changed but little relatively, and most of them decreased slightly in proportion. The stomachs and liver became a slightly increased proportion as the animal got heavier and fatter, and consumed more feed.

PROPORTION OF CUTS OF MEAT

Table 35 gives the distribution of the various wholesale butcher's cuts of meat in the empty animal and in the carcass. Since but one-half of the animal was divided in this manner the weights shown in the table are double the right side weights and will differ somewhat

from the true total weights. An idea of the amount and direction of this difference can be obtained by comparing the weights here with those in Table 34. The animals are arranged in the order of increasing fatness.

TABLE 35.—PROPORTION OF CUTS TO EMPTY WEIGHT AND TO CARCASS

Steer	18	197	588	121	589	164	48
Age	3 yr.	3 yr.	5 yr.	scant	5 yr.	3 yr.	5 yr.
		2 mo.	6½ mo.	3 yr.	3½ mo.	7 mo.	
Warm empty weight, grams	302,183	444,750	485,754	508,513	564,913	608,656	744,708
Weight of carcass, grams.....	202,776	308,714	335,642	345,864	394,562	413,306	518,794
Forequarters,							
per cent empty weight.....	35.725	36.982	37.631	36.750	39.003	35.352	36.412
Forequarters, per cent carcass	53.238	53.280	54.462	54.033	55.843	52.062	52.268
Hind quarters,							
per cent empty weight.....	31.379	32.430	31.465	31.264	30.842	32.552	33.252
Hind quarters, per cent carcass	46.762	46.721	45.538	45.967	44.157	47.938	47.732
Shins, per cent empty weight	3.452	3.526	2.521	3.032	3.533	2.366	2.141
Shins, per cent carcass.....	5.145	5.079	3.649	4.458	5.058	3.485	3.074
Necks, per cent empty weight	1.051	0.920	0.560	0.710	0.835	0.621	0.649
Necks, per cent carcass.....	1.566	1.325	0.811	1.044	1.196	0.915	0.932
Chucks, per cent empty weight	17.637	17.320	18.676	15.589	16.168	17.641	15.958
Chucks, per cent carcass.....	26.283	24.951	27.029	22.919	23.148	25.979	22.907
Plates, per cent empty weight	7.355	9.012	9.151	10.528	10.278	8.299	9.782
Plates, per cent carcass.....	10.961	12.983	13.244	15.478	14.715	12.221	14.041
Ribs, per cent empty weight....	6.229	6.203	6.723	6.832	8.190	6.391	7.882
Ribs, per cent carcass.....	9.283	8.936	9.730	10.046	11.726	9.412	11.314
Loins, per cent empty weight	10.958	11.455	12.606	12.087	11.154	11.682	12.892
Loins, per cent carcass.....	16.329	16.503	18.244	17.771	15.969	17.204	18.506
Kidney fat and kidneys,							
per cent empty weight.....	1.062	0.693	0.746	1.646	2.534	1.160	2.470
Kidney fat and kidneys,							
per cent carcass.....	1.581	0.999	1.080	2.420	3.628	1.708	3.546
Flanks, per cent empty weight	1.620	2.377	2.614	1.713	2.953	3.002	3.428
Flanks, per cent carcass.....	2.414	3.424	3.784	2.518	4.227	4.420	4.921
Rumps, per cent empty weight	2.326	2.632	3.455	2.345	1.903	2.738	2.634
Rumps, per cent carcass.....	3.467	3.792	5.000	3.448	2.724	4.032	3.781
Rounds, per cent empty weight	12.759	12.850	12.046 ¹	11.567	10.642	11.319	10.271
Rounds, per cent carcass.....	19.014	18.513	17.434 ¹	17.007	15.237	16.669	14.743
Shanks, per cent empty weight	2.665	2.407	.....	1.849	1.657	1.758	1.551
Shanks, per cent carcass.....	3.971	3.467	.....	2.718	2.372	2.589	2.228
Head, ² per cent empty weight	3.465	2.535	2.854 ³	2.443	2.266	2.215	1.820
Tail, per cent empty weight	0.212	0.216	0.176	0.146	0.134	0.171	0.111

¹Inclusive shank.

²Exclusive horn, teeth, brain, and tongue.

³Inclusive teeth.

It is quite characteristic of this type of beef cattle that the fore quarter is heavier than the hind quarter. The Hereford is particularly light in the rear. The fore quarter is a larger part of the empty animal and of the carcass than the hind quarter. These investigations indicate that from 53 to 54 per cent of the carcass is fore

quarter and from 46 to 47 per cent is hind quarter. The weight of the fore quarter is a little over one-third of the empty animal and the hind quarter is a little over 30 per cent.

This investigation shows further that the shin, shank, and the neck, three of the cheaper cuts of meat, form a smaller part of the animal as it becomes fatter. The round, one of the better cuts of meat, also decreases relatively. The chuck varies somewhat, but it averages a smaller part of the fatter animal. The plate forms a larger part of the fatter animal and this is largely because it is a depot for the storage of fat. The rib, one of the high priced cuts of meat, forms a larger part of the animal as it becomes fatter. The loin, the highest priced cut of meat, increases relatively faster even than the rib cut. The kidney and kidney fat increase rapidly and form over twice as large a part of the total in the fat animal as they do in the thin animal. The same is true of the flank. These are all depots for the storage of fat. The rump seems to vary without respect to the condition of the animal. Both the head and tail form a smaller part of the animal as it becomes fatter.

Therefore, the shin, shank, head, tail, and neck—all cheap and comparatively waste cuts of meat—decrease relatively as the animal fattens. The same is true of the round which is not a depot for fat storage. The loin, rib, plate, flank, and kidney and kidney fat—all depots for fat storage—increase relatively as the animal fattens. The latter group is about equally divided between high priced and cheap cuts of meat.

The biggest single cut of the carcass is the chuck which is about one-fourth of the total. The shin is 5 per cent and below. The neck is below 2 per cent. The plate is 10 to 15 per cent, and the rib from 9 to 12 per cent.

In the hind quarter, the loin is from 16 to 18.5 per cent of the carcass. The kidney fat and kidney is from 1 to 3.6 per cent. The flank is from about 2.5 per cent to 5 per cent. The rump is from 2.7 per cent to 5 per cent. The round runs from 15 to 19 per cent and the shank from 2 to 4 per cent of the carcass.

DISTRIBUTION OF PARTS OF TOTAL ANIMAL

Table 36 shows how the warm empty weight of the animal is divided between carcass, blood and organs, hide and hair, and sundry other offal parts. The head, tail, and feet include the horns, hoofs, teeth, and dew claws. Both the per cents and the weights in grams are given. The parts constitute from 96.5 to 99 per cent of

the total warm empty weight. The carcass weight is the chilled weight taken after it had hung two days. It had consequently lost considerable moisture. The difference was from 1 to 3.5 per cent of the warm empty weight. It is probable that this difference is due entirely to the drying of the carcass.

TABLE 36.—MAIN DIVISIONS OF EMPTY ANIMAL AND LOSS FROM COOLING
Weights of parts in grams

Steer	18	197	588	121	589	164	48
Warm empty weight.....	302,183	444,750	485,754	508,513	564,913	608,656	744,708
Carcass ¹	201,543	309,604	334,894	348,064	394,509	412,178	524,189
Offal fat	5,700	11,028	13,910	27,376	22,494	23,532	61,837
Hide and hair	25,674	35,209	38,188	29,564	45,681	46,266	41,164
Head, tail, feet, etc.	19,667	23,555	23,573	22,406	22,278	23,444	24,820
Blood and organs	43,817	55,436	58,131	73,820	74,215	85,958	84,099
Loss on cooling	5,782	9,918	17,058	7,283	5,736	17,278	8,599

Per cent of Parts to Warm Empty Weight

Carcass	66.696	69.613	68.942	68.445	69.836	67.720	70.389
Offal fat	1.886	2.480	2.864	5.386	3.982	3.866	8.304
Hide and hair	8.496	7.917	7.862	5.814	8.086	7.601	5.528
Head, tail, feet, etc.	6.508	5.296	4.853	4.406	3.944	3.852	3.333
Blood and organs	14.500	12.465	11.967	14.517	13.137	14.123	11.293
Total	98.086	97.771	96.188	98.568	98.985	97.162	98.847
Loss on cooling	1.914	2.229	3.512	1.432	1.015	2.838	1.153

¹The kidneys are excluded.

The carcass, offal fat, and hair and hide have already been discussed.

The organs and blood of the animal form from 11.3 to 14.5 per cent of the total. The largest animal in the experiment gave the lowest, and the thinnest animal gave the highest proportion of organs and blood to total weight. The others varied somewhat, but followed the general tendency fairly well.

The head, tail, feet, and their horny and bony appendages were found to be a smaller part of the animals as they became fatter. The percentage dropped from 6.5 per cent to 3.3 per cent.

PROPORTION OF LEAN, FAT, AND BONE IN WHOLESALE CUTS

It has been shown that certain of the wholesale cuts of meat increase in proportion to the carcass and empty animal as the animal fattens. It was stated that these cuts of meat were depots for fat storage. Just how much of the increase is due to the fat laid on can be shown by a study of the proportion of lean, fat, and bone in animals of different degrees of fatness. In Table 37 are given the

per cents of each in the cuts of the fore quarter for the four steers that were used for the chemical analysis. The cuts of only these four were separated by hand into lean flesh, fatty tissue, and bone. Table 38 gives the results for the divisions of the hind quarter. The animals are arranged in the order of increasing fatness.

TABLE 37.—PROPORTION OF LEAN, FAT, AND BONE IN THE CUTS OF THE FOREQUARTER

Steer	18	197	121	48
Age	3 yr.	3 yr. 2 mo.	3 yr.	5 yr.
Per cent Lean in shin	44.862	51.543	52.173	50.031
Per cent Fat in shin	8.340	11.352	13.115	11.965
Per cent Bone in shin	45.667	36.913	34.142	37.677
Per cent Lean in neck	71.977	62.610	54.319	51.696
Per cent Fat in neck	none	12.072	21.872	30.438
Per cent Bone in neck	24.559	25.171	23.643	17.742
Per cent Lean in chuck	71.409	67.365	62.783	58.829
Per cent Fat in chuck	6.875	14.348	21.365	27.826
Per cent Bone in chuck	21.056	18.090	15.088	12.861
Per cent Lean in plate	52.947	46.599	53.891	38.012
Per cent Fat in plate	23.585	38.182	34.274	52.250
Per cent Bone in plate	22.406	14.660	11.473	9.412
Per cent Lean in rib	65.544	58.562	61.133	41.313
Per cent Fat in rib	7.554	21.219	21.466	46.015
Per cent Bone in rib	25.032	19.980	17.154	12.426

TABLE 38.—PROPORTION OF LEAN, FAT, AND BONE IN THE CUTS OF THE HINDQUARTER

Steer	18	197	121	48
Age	3 yr.	3 yr. 2 mo.	3 yr.	5 yr.
Per cent Lean in loin	68.525	60.183	54.808	44.949
Per cent Fat in loin	13.475	24.413	33.286	45.649
Per cent Bone in loin	17.069	14.709	11.119	9.758
Per cent Lean in flank	57.090	38.082	46.269	26.434
Per cent Fat in flank	40.989	60.821	53.203	73.276
Per cent Bone in flank	1.921	1.059	0.390	0.313
Per cent Lean in rump	51.323	41.671	44.726	36.130
Per cent Fat in rump	19.004	30.856	32.903	45.866
Per cent Bone in rump	27.084	27.029	22.220	17.943
Per cent Lean in round	79.064	69.905	72.163	65.741
Per cent Fat in round	7.340	17.690	17.000	25.520
Per cent Bone in round	13.191	11.468	9.180	8.260
Per cent Lean in shank	30.849	34.996	28.079	30.888
Per cent Fat in shank	5.564	10.781	13.529	12.459
Per cent Bone in shank	61.674	54.671	57.817	56.446

In three cases out of four the per cent of both lean and fat in the shin increased, and the per cent of bone decreased as the animals fattened. The fact that Steer 48 gave a higher per cent of bone in

this cut than Steers 197 and 121 may indicate that it was a bigger boned animal.

The per cent of lean and bone decreased, and that of fat flesh increased as the animals fattened. The increase in fat flesh varied from an amount so small that it could not be separated to more than 30 per cent. The chuck made very much the same change. The plate made the same sort of change but to a greater extent. More than half of the cut of Steer 48 was hand-separable fat flesh. The rib also made a great increase in fat as the animals fattened and a decrease in per cent of lean flesh and bone. The fatty flesh increased from less than 8 per cent to more than 46 per cent.

In the hind quarter the loin, the flank, and the rump all increased in per cent of fatty flesh and decreased in per cent of lean flesh and bone as the animals fattened. The flank aside from the kidney fat was the fattest cut of all the wholesale cuts. It contained from about 40 per cent to more than 73 per cent of fatty flesh. The round was found to be the leanest cut of all, since it contained from 79 to 65 per cent of lean flesh. It increased in fat flesh and decreased in lean and bone considerably as the animals fattened. The shank increased in fat flesh but did not decrease proportionately in the lean flesh and bone. There was but little change in the per cent of lean flesh, since the thinnest and fattest animals both yielded about 30 per cent. The other two varied from this a few per cent. The bone was a smaller per cent of the cut in the fat animals than in the thin one, but it did not decrease in proportion to the increase in fat. This was the boniest cut of all, and bore about 62 to 54 per cent of bone.

The greatest increases in per cent of fatty flesh in the cut were found in those cuts which form a relatively larger part of the carcass as the animal fattens. This increase was consequently due largely to the deposit of fat. The weight of lean flesh and bone increased also, but not nearly so rapidly as the fat flesh.

DISTRIBUTION OF LEAN FLESH IN THE ANIMAL

As the mature beef animal grows and fattens, is the distribution of the lean meat, or lean flesh, affected and, if so, what parts grow more than others? If fattening increases the relative amount of lean in the cheap cuts, or in the expensive cuts, it is a fact worth knowing in order to form a basis for determining a standard to which to conform when fattening beef steers. Table 39 shows how the total lean flesh was distributed in the four animals used for chemical analysis.

But a small part of the total lean of the animal was found in the head and the amount was relatively less in the fat steers than in the thinnest steer. Yet Steer 197, which was rather thin, yielded about as little as the fatter animals. The per cent of total lean found in the shin varied without respect to condition and on the whole was fairly constant. The neck showed about the same tendency as the head. In no one of these cuts did the lean form an appreciable part, only 1 to 4 per cent, of the whole lean.

TABLE 39.—DISTRIBUTION OF LEAN FLESH IN THE ANIMAL

Steer	18	197	121	48
Age	3 yr.	3 yr. 2 mo.	3 yr.	5 yr.
Per cent total lean in head	2.209	1.454	1.549	1.217
Per cent total lean in shin	3.483	4.400	3.995	3.238
Per cent total lean in neck	1.701	1.395	0.974	1.015
Per cent total lean in chuck	28.325	28.252	24.714	28.378
Per cent total lean in plate	8.758	10.169	14.326	11.240
Per cent total lean in rib	9.183	8.796	10.547	9.843
Per cent total lean in loin	16.887	16.694	16.728	17.516
Per cent total lean in flank	2.079	2.192	2.001	2.739
Per cent total lean in rump	2.685	2.656	2.649	2.877
Per cent total lean in round	22.688	21.752	21.079	20.411
Per cent total lean in shank	1.849	2.040	1.311	1.449
Per cent total lean in tail	0.164	0.199	0.126	0.077

About 28 per cent of the total lean of the animal was found in the chuck, and the fatness of the steer had no effect upon the per cent. Steer 121 gave less than 25 per cent.

The per cent of total lean found in the plate increased as the animals fattened. Less than 9 per cent of the total lean of Steer 18 was in this cut, while more than 14 per cent of the lean in Steer 121 was in the plate. However, 11 per cent of the lean in Steer 48 was in this cut. The proportion of lean in the rib, loin, and flank to the total lean flesh was about constant. The rib was about 9 per cent of the total lean, the loin about 17 per cent, and the flank only about 2 per cent. Steer 48 had a little more of the total lean in the loin and flank than the others. The rump also was found to contain a constant part of the total lean, or a bit under 3 per cent.

The round contained less and less of the total lean as the animals fattened, and dropped from about 22.7 per cent to 20.4 per cent. In the shank and in the tail the two fattest animals had a smaller per cent of the total lean than the thinner animals. The change in amount was small, however. The shank contained less than 2 per cent and the tail less than 0.2 per cent of the total lean.

All but two of the cuts contained a constant part of the total lean. As the animals fattened the proportion of lean increased in the plate and decreased in the round. Fattening had practically no effect upon the relative distribution of the lean.

DISTRIBUTION OF FAT FLESH IN THE ANIMAL

Table 40 shows the distribution of fat flesh, exclusive of offal fat, in the animals. The head contained less than two per cent of the total fat and this per cent decreased as the animals fattened. The fat in the shin, likewise, became a smaller part of the total fat as the animals fattened and decreased from about 3.5 per cent to less than 0.9 per cent. The neck contained but very little of the total fat. The fat of the neck increased, however, until the animals reached the half-fat condition. Then there was a decrease.

TABLE 40.—DISTRIBUTION OF FAT FLESH (EXCLUSIVE OF OFFAL FAT) IN THE ANIMAL

Steer	18	197	121	48
Age	3 yr.	3 yr. 2 mo.	3 yr.	5 yr.
Per cent total fat in head	1.733	1.277	1.173	0.629
Per cent total fat in shin	3.458	2.487	2.145	0.898
Per cent total fat in neck		0.690	0.838	0.692
Per cent total fat in chuck	14.563	15.444	17.964	15.555
Per cent total fat in plate	20.835	21.385	19.462	17.904
Per cent total fat in rib	5.652	8.180	7.911	12.705
Per cent total fat in kidney fat.....	9.714	3.217	7.713	8.077
Per cent total fat in loin	17.734	17.380	21.700	20.615
Per cent total fat in flank	7.973	8.985	4.915	8.799
Per cent total fat in rump	5.310	5.047	4.162	4.233
Per cent total fat in round	11.248	14.127	10.607	9.182
Per cent total fat in shank	1.781	1.613	1.349	0.677
Per cent total fat in tail		0.168	0.062	0.034

The chuck contained about 15 per cent of the total fat. Fattening at first slightly increased this per cent and then decreased it. Of the total fat, from 18 to 21 per cent was found in the plate, but relatively less of the total was found in this cut from the fatter animals. Fattening increased the per cent of the total fat found in the rib cut. In these experiments an increase from 5.65 per cent to 12.7 per cent of the total was found.

The per cent of the total fat found in the kidney fat was greatest in the very thin steer. But in the other three relatively more was found as they fattened. The loin contained from 17 to 21.7 per cent of the total fatty tissue. The larger per cents of the total were

found in the two fatter animals. The change in the per cent of total fat found in the flank was small and did not follow the condition of the animal. The fat of the flank varied from 8 to 9 per cent of the total fat, altho in Steer 121 it was less than 5 per cent. The rump contained less of the total in the fat animals than in the thin animals. The values were 4 and 5 per cent respectively. A similar condition exists in the round. It contained from 9 to 14 per cent of the total fat. The shank and tail contained less and less of the total fat as the animals fattened. The shank contained less than 2 per cent of the total fat and the tail less than 0.2 per cent.

Steer 18 was very thin and in some cases it was impossible to find enough fatty tissue to separate. This accounts for the absence of figures for the neck and tail.

In general, there were no great changes in the fat distribution as the animals fattened. The proportion of the total fat in the rib and loin increased as the animals fattened. In the case of the chuck and the kidney fat the evidence indicates a similar tendency, but in each case the data for one of the animals failed to agree with that of the others. In all the other cuts there was a slight decrease in the proportion of the total fat found in the rib and loin as the animals fattened.

DISTRIBUTION OF THE SKELETON IN THE ANIMAL

Table 41 shows the distribution of the total skeleton in the animal. A general survey of the figures in the table shows that fattening had practically no effect upon the distribution of the skeleton

TABLE 41.—DISTRIBUTION OF SKELETON IN THE ANIMAL

Steer _____ Age _____	18 3 yr.	197 3 yr. 2 mo.	121 3 yr.	48 5 yr.
Per cent total skeleton in head.....	12.550	11.222	12.797	11.774
Per cent total skeleton in shin.....	8.177	8.233	7.929	7.541
Per cent total skeleton in neck.....	1.339	1.465	1.286	1.077
Per cent total skeleton in chuck.....	19.261	19.819	18.014	19.180
Per cent total skeleton in plate.....	8.548	8.358	9.251	8.605
Per cent total skeleton in rib.....	8.088	7.840	8.977	9.155
Per cent total skeleton in loin.....	9.701	10.659	10.293	11.759
Per cent total skeleton in flank.....	0.161	0.159	0.051	0.100
Per cent total skeleton in rump.....	3.268	4.500	3.991	4.418
Per cent total skeleton in round.....	8.730	9.180	8.134	7.930
Per cent total skeleton in shank.....	8.524	8.324	8.188	8.189
Per cent total skeleton in tail.....	0.796	0.782	0.651	0.710
Per cent total skeleton in feet.....	10.858	10.028	10.438	9.557

among the various cuts and offal parts of the skeleton. The proportion of skeleton in the loin and rib increased as the animals fattened. The proportion of a few of the other cuts such as head, shin, decreased slightly.

The following is an approximate division of the total skeleton as indicated by the steers in question: head 12 per cent, shin 8 per cent, neck 1 per cent, chuck 19 per cent, plate 8.5 per cent, rib 8 to 9 per cent, loin 9 to 11 per cent, flank 0.1 per cent, rump about 4 per cent, round 8 to 9 per cent, shank 8 per cent, tail less than 0.8 per cent, and feet 10 to 11 per cent.

PROPORTION OF LEAN, FAT, AND BONE IN EMPTY ANIMAL AND IN CARCASS

Table 42 shows the proportion of skeleton, lean flesh, and fat flesh to total animal and carcass. As the animals fattened the skeleton decreased from 19 per cent of the empty animal to nearly 10 per cent. The lean flesh decreased from 44 to 33 per cent. That fatty tissue that is included in the carcass increased from 8 to 28 per cent. This increase in fat was as striking when the total fat including the offal fat was considered. It constituted 10 per cent of the total empty animal in the very thin steer and nearly 37 per cent in the very fat steer. In this case, considerably over one-third of the empty animal was hand-separable fat. In three of the animals more than one-fourth of the total fatty tissue was in the kidney and offal fats. Steer 197 had a low weight of both offal and kid-

TABLE 42.—DISTRIBUTION OF LEAN, FAT, AND BONE
Proportion of lean, fat, and bone in empty animal

Steer	18	197	121	48
Age	3 yr.	3 yr. 2 mo.	3 yr.	5 yr.
Per cent skeleton	19.280	15.808	13.056	10.698
Per cent lean flesh	44.469	41.297	39.601	33.082
Per cent fatty tissue (excl. offal fat).....	8.326	16.089	18.540	28.547
Per cent total fatty tissue	10.212	18.569	23.924	36.850
Per cent offal and kidney fats to total fatty tissue.....	26.390	16.141	28.481	28.790

Proportion of lean, fat, and bone in the carcass

Per cent skeleton	21.778	17.756	14.611	11.972
Per cent lean flesh	64.697	58.511	57.249	46.873
Per cent fatty tissue	12.193	22.846	26.922	40.706
Per cent kidney fat to fatty tissue in carcass	9.885	3.264	7.810	8.131

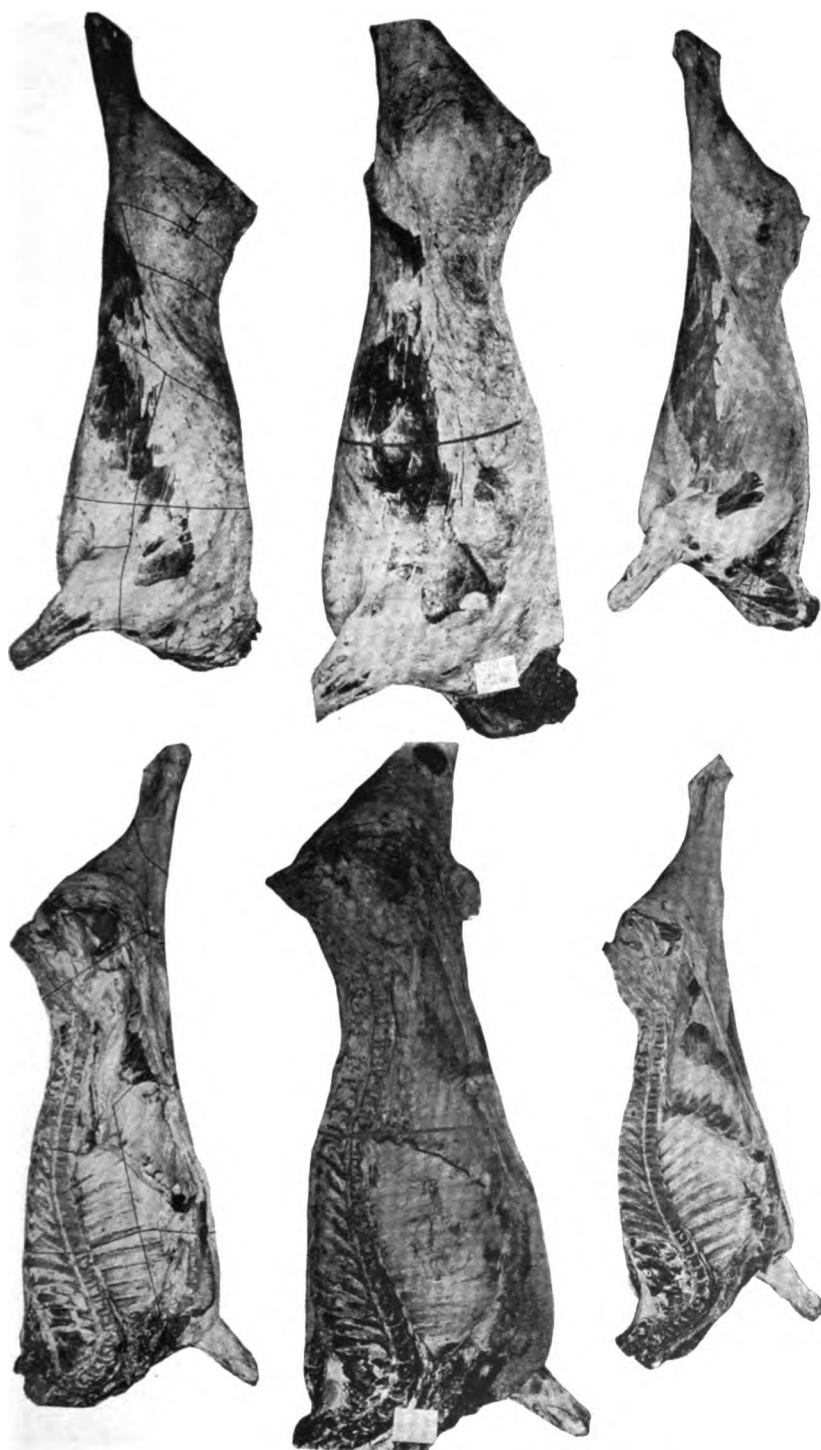


PLATE VIII.—Carcasses of Steers 121, 48, and 18

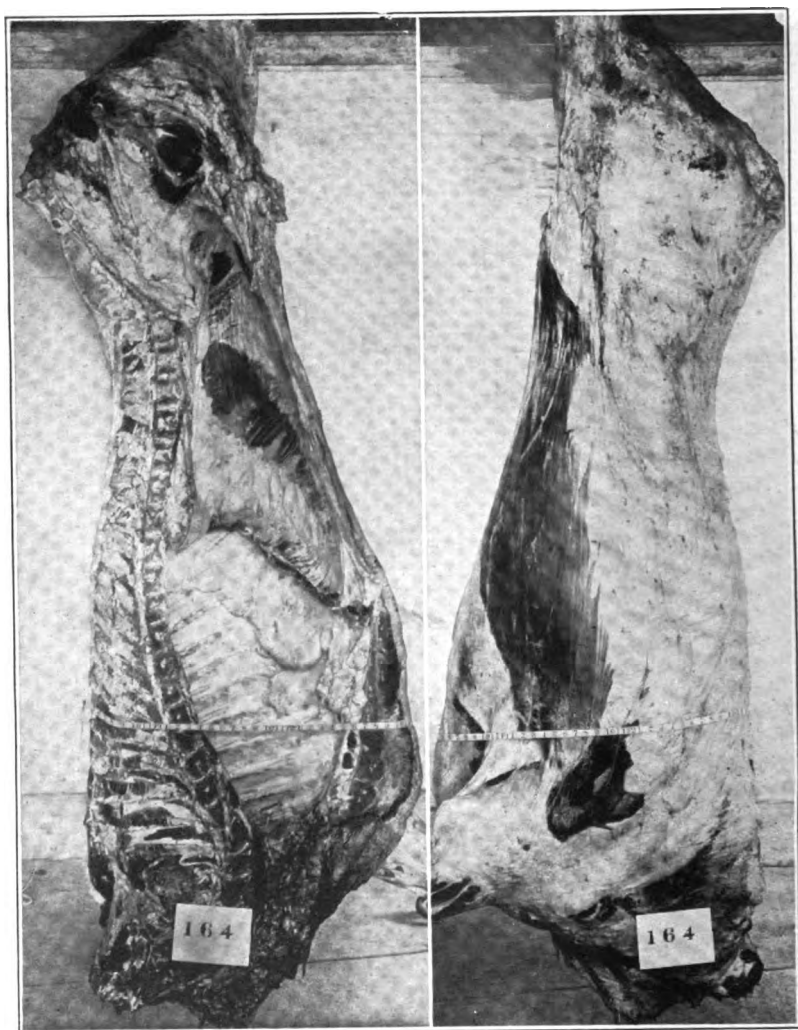


PLATE IX.—Carcass of Steer 164

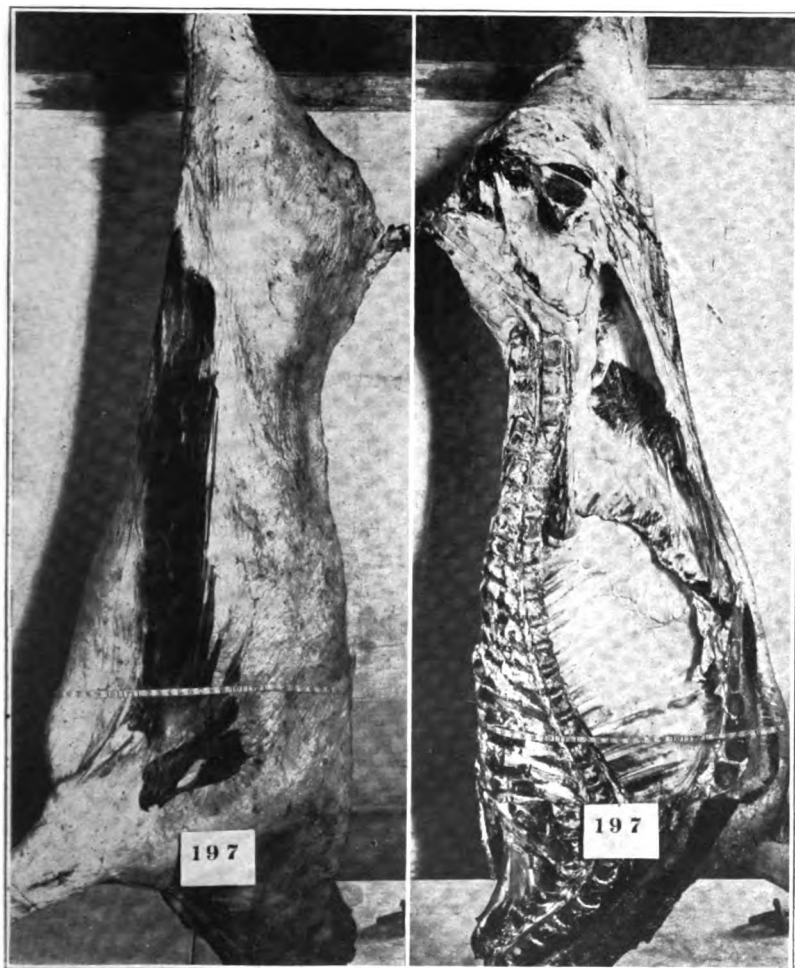


PLATE X.—Carcass of Steer 197

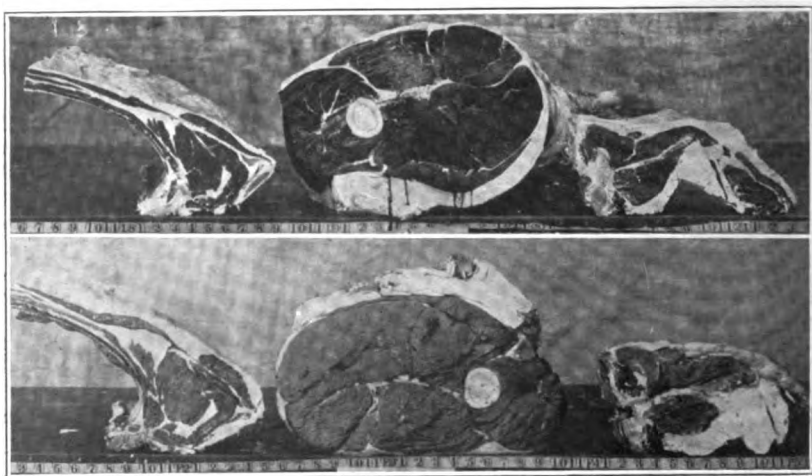
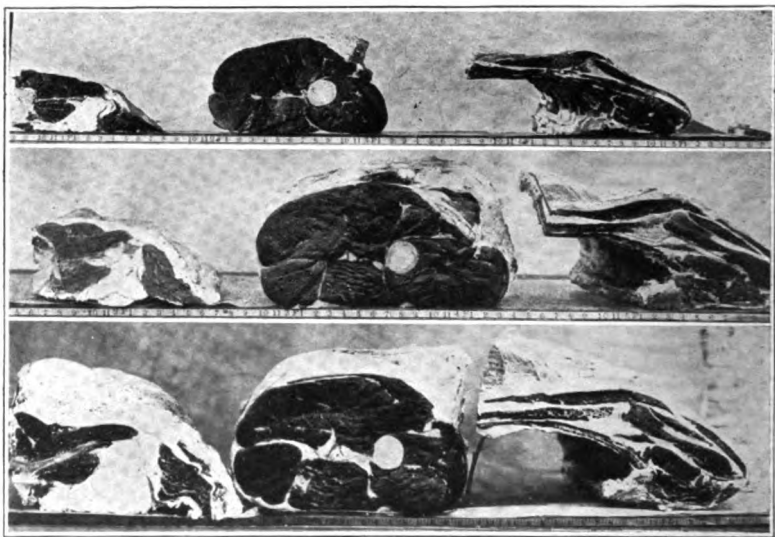


PLATE XI.—Loin, round and rib: Above, Steers 18, 121, and 48; below, Steers 164 and 197

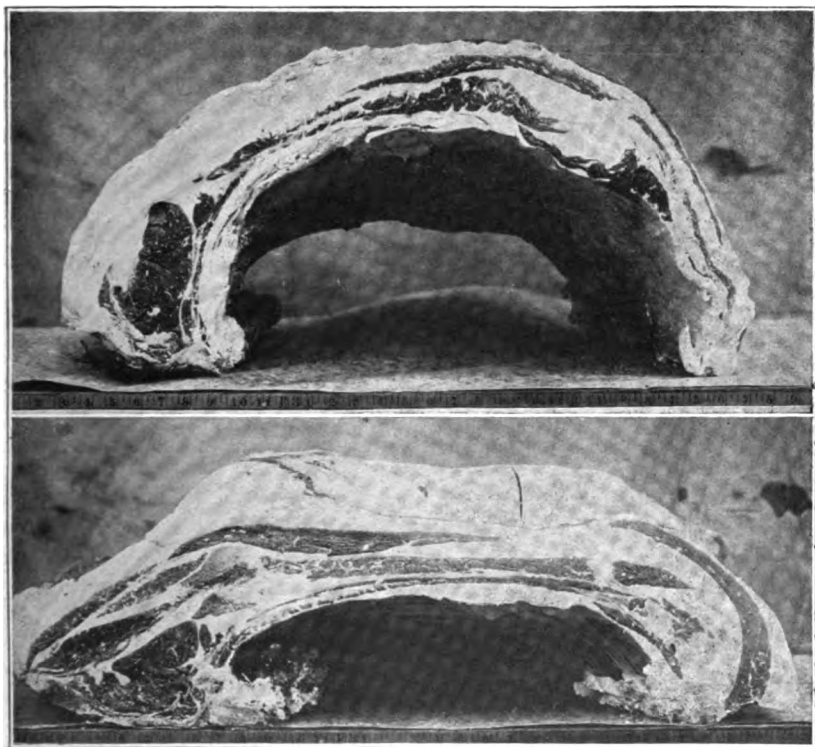


PLATE XII.—Cross sections of carcass of Steer 48: Above, at twelfth rib; below, at fifth rib

ney fats, and only one-sixth of the total fatty tissue was found in these parts.

In the thin animals more than 21 per cent of the carcass was skeleton. This per cent decreased as the animals fattened, and became less than 12 per cent in the very fat steer. About 65 per cent of the very thin steer's carcass was lean flesh. The lean decreased as the animals fattened and became less than 47 per cent in the fat-test animal. The fatty tissue in the carcass increased from about 12 per cent to more than 40 per cent. The kidney fat did not form a large part of the carcass fat, since it was only 10 per cent of the carcass in the thinnest steer and about 8 per cent in the two fat steers. On account of the very low weight of kidney fat in Steer 197 only a little more than 3 per cent of the carcass fat was found in this part. Figure 25 shows graphically the distribution of skeleton, lean flesh, fat flesh, and viscera.

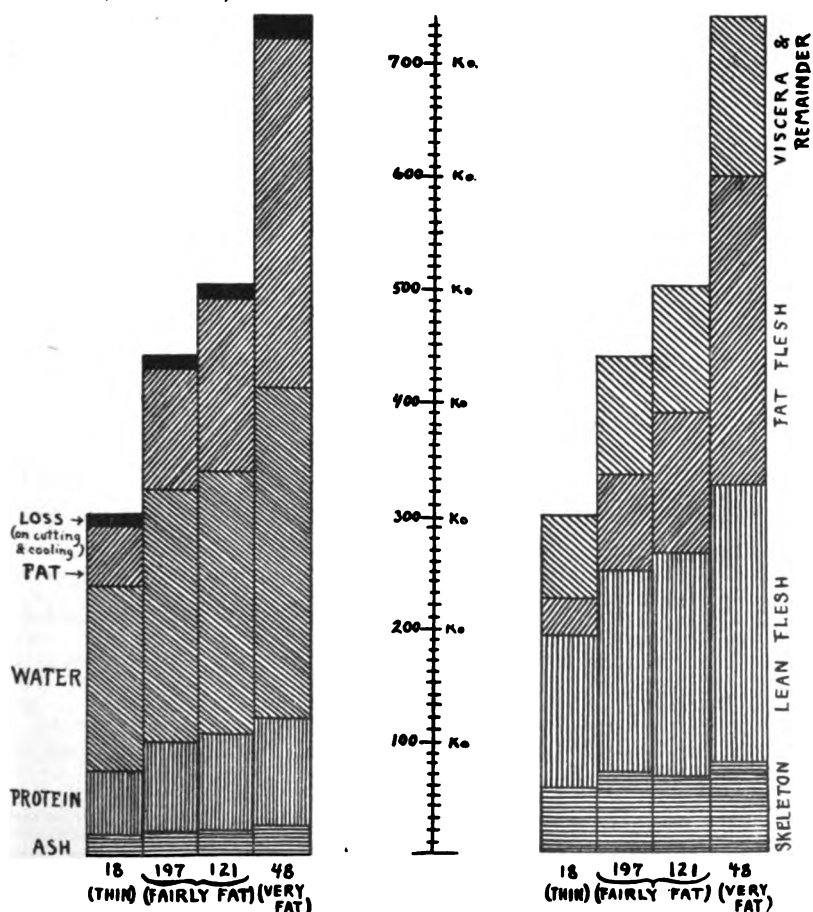


Fig. 25.—Composition of the entire animal

PHOTOGRAPHS OF CARCASSES AND TYPICAL CUTS

Photographs of the inside and outside of the carcass of each steer and of three typical cuts of meat from each are shown in Plates VIII to XII.

Steer 18 produced an exceedingly lean carcass. The flesh was exposed over a greater part of the surface, and there was very little kidney fat. Steer 121 produced a well-covered carcass and a good supply of kidney fat. The inside of the ribs was partly covered with fat. Steer 48 was excessively fat. The outside of the carcass was patchy with fat, the kidney and cod fat were excessive, and the ribs were entirely covered with fat.

Steer 164 produced a fat, smooth carcass. The kidney and cod fats were not excessive. Heavy plates of fat were noticeable on the inside of the ribs. Steer 197 produced a fairly well covered carcass but it was a bit thin. There were some plates of fat still remaining on the ribs, altho the animal had been on maintenance a long time.

In Plate XI is shown very strikingly the differences between the first three steers. The small size and leanness of the cuts of Steer 18 were quite a contrast to the excellent cuts of Steer 121. Steer 48 was excessively fat, especially in the loin cut where the fat occupied considerably more than half the area. A great amount of this fat would have been wasted, had the carcass been placed on the market. The cuts of Steer 164 and Steer 197 showed that these animals were in about the same condition as Steer 121, that is, they were well fattened. Steer 197 had been reduced to this condition by a long maintenance period. It must have been quite fat at the start.

CHEMICAL DATA AND RESULTS

Four of the seven animals were used for a chemical analysis. The other animals had been used only for the feeding and slaughtering data. The results from samples analyzed are shown in Tables 43 to 46. The weights of the parts together with the weights of water, fat, nitrogen, ash, and phosphorus as found by analysis are given in Tables 47 to 50.

TABLE 43.—PERCENTAGE COMPOSITION OF SAMPLES OF STEER 18

Sample	Per cent water	Per cent fat	Per cent nitrogen	Per cent ash	Per cent phosphorus	Weight grams
Blood	81.290	0.429	2.909	0.688	0.022	15,599
Hide and hair	65.365	2.883	5.096	0.868	0.068	25,674
Skeleton	28.292	25.272	3.022	25.326	2.879 ^a	58,261
Circulatory system	56.503	30.068	1.996	0.751	0.123	2,594
Respiratory system	74.710	6.461	2.756	0.959	0.151	3,079
Nervous system	68.830	17.625	1.750	1.757	0.422	722
Digestive and Excretory System ¹	66.510	18.128	2.093	1.634	0.129	18,436
Liver	68.990	3.469	3.026	1.253	0.311	2,625
Kidneys	75.046	8.736	2.373	1.085	0.211	762
Shin, shank, head and tail, lean and fat	67.433	11.990	3.219	0.771	0.145	12,106
Round and rump, lean and fat	66.503	13.258	3.110	0.883	0.172	38,258
Loin, lean and fat	59.900	21.719	2.866	0.788	0.157	27,152
Flank and plate, lean and fat...	52.512	30.103	2.440	0.649	0.124	21,810
Rib, lean and fat	62.790	18.037	3.076	0.821	0.161	13,760
Chuck and neck, lean and fat...	66.480	14.068	3.019	0.818	0.154	44,008
Offal fat	16.620	79.718	0.517	0.172	0.027	5,700
Kidney fat	10.044	86.962	0.421	0.120	0.021	2,444
Teeth	21.947	0.461	2.061	61.324	11.562	682
Horns, hoofs and dew claws ²...	.....	.....	.....	.....	.....	1,346

¹Less liver and kidneys.

²Accidental loss of two of the three samples used for water and fat determinations and the ashing of the one left in a platinum dish make this phosphorus data unreliable. A value more to be expected is 4.8 per cent.

^aThis sample was lost.

TABLE 44.—PERCENTAGE COMPOSITION OF SAMPLES OF STEER 121

Blood	77.971	none	3.255	0.248	0.028	24,433
Hide and hair	59.764	4.969	5.534	0.758	0.056	29,662
Skeleton	29.653	21.185	3.500	27.108	4.806	66,391
Circulatory system ¹	27.420	65.274	0.954	0.205	0.039	2,677
Lean heart	77.383	4.391	2.571	1.000	0.211	1,596
Respiratory system	63.955	19.692	2.308	0.808	0.170	4,631
Nervous system	68.357	19.499	1.676	1.562	0.395	710
Digestive and excretory system ²	55.535	31.725	1.611	0.633	0.126	15,525
Tongue, marketable	60.397	25.272	2.225	0.642	0.132	1,862
Stomachs	78.260	8.209	1.764	0.971	0.200	14,253
Liver	68.360	4.716	3.191	1.312	0.353	7,035
Kidneys	76.580	5.560	2.738	0.950	0.229	1,098
Shin, shank, head and tail, loin and fat	62.295	18.183	2.929	0.733	0.142	18,516
Round and rump, lean	69.963	8.183	3.283	0.957	0.191	47,782
Round and rump, fat	14.410	80.605	0.617	0.153	0.030	13,924
Loin, lean	67.220	11.396	3.008	0.943	0.185	33,686
Loin, fat	9.075	87.840	0.396	0.133	0.024	20,458
Flank and plate, lean and fat...	40.073	47.701	1.924	0.500	0.095	55,862
Rib, lean	60.980	20.874	2.786	0.777	0.153	21,240
Rib, fat	10.677	86.035	0.453	0.135	0.027	7,458
Chuck and neck, lean and fat...	59.141	24.425	2.605	0.702	0.142	69,456
Kidney fat	4.484	94.670	0.181	0.070	0.012	7,272
Offal fat	9.517	88.015	0.273	0.129	0.022	27,376
Teeth	11.401	0.618	2.410	69.227	13.813	556
Hoofs and dew claws ³ .....	.....	.....	.....	.....	.....	1,480

¹Less the lean heart.²Less the tongue, stomachs, liver and kidneys.³This sample was lost.

TABLE 45.—PERCENTAGE COMPOSITION OF SAMPLES OF STEER 48

Sample	Per cent water	Per cent fat	Per cent nitrogen	Per cent ash	Per cent phosphorus	Weight grams
Blood	79.410	none	3.158	0.775	0.021	25,634
Hide and hair	59.240	8.600	5.308	1.197	0.048	41,164
Skeleton (composited)	28.318	21.153	3.139	26.757	4.980	.....
Circulatory system ¹	10.070	88.450	0.284	0.145	0.026	4,207
Heart, marketable	65.830	19.450	2.126	0.835	0.158	2,573
Respiratory system	49.420	37.390	1.957	0.669	0.117	10,970
Nervous system	69.630	13.050	2.093	1.813	0.425	774
Digestive and excretory system ²	64.160	22.410	1.778	0.697	0.128	14,059
Tongue, marketable	56.020	29.500	2.273	0.743	0.126	2,376
Stomachs	74.750	11.940	1.757	1.073	0.227	14,113
Liver	69.730	4.260	2.893	1.392	0.307	8,166
Kidneys	70.750	12.160	2.446	1.154	0.199	1,227
Shin, shank, head and tail, lean and fat	57.840	23.470	2.853	0.829	0.142	19,494
Rump, lean and fat	36.910	52.670	1.587	0.509	0.093	16,086
Round, lean	64.430	13.420	3.278	1.015	0.192	50,284
Round, fat	27.750	67.350	0.765	0.251	0.027	19,520
Loin, lean	61.780	18.260	2.981	0.956	0.174	43,154
Loin, fat	12.600	84.760	0.426	0.146	0.023	43,826
Flank and plate, lean and fat....	30.150	61.110	1.308	0.421	0.064	91,206
Rib, lean	56.860	24.790	2.679	0.827	0.150	24,250
Rib, fat	15.810	81.370	0.431	0.155	0.021	27,010
Chuck and neck, lean and fat	49.670	34.950	2.267	0.693	0.123	106,952
Offal fat	6.220	92.090	0.182	0.093	0.012	61,837
Kidney fat	3.760	94.710	0.239	0.126	0.016	17,170
Teeth ³ .....	.....	.....	.....	.....	.....	712
Hoofs and dew claws ³ .....	.....	.....	.....	.....	.....	1,675
Skeleton of head, tail and feet	37.050	11.519	3.429	24.510	4.635	17,559
Skeleton of shin and shank	20.710	24.344	3.202	33.040	6.173	12,532
Skeleton of flank and plate	37.730	19.567	2.999	20.220	3.772	6,936
Skeleton of chuck and neck	27.780	18.655	3.527	27.530	5.073	16,142
Skeleton of round	23.160	32.479	2.124	27.070	5.020	6,318
Skeleton of rump	26.290	35.688	2.294	20.650	3.891	3,520
Skeleton of loin	21.550	29.603	2.820	26.090	4.805	9,368
Skeleton of rib	26.750	18.359	3.303	29.410	5.416	7,294

¹Less the marketable heart.²Less the tongue, stomachs, liver, and kidneys.³This sample was lost.TABLE 46.—PERCENTAGE COMPOSITION OF SAMPLES OF STEER 19^a

Blood	78.731	none	3.260	0.660	0.026	20,067
Hide and hair	61.293	4.888	5.456	0.934	0.050	35,209
Circulatory system	54.502	32.638	1.807	0.822	0.117	3,806
Respiratory system	78.352	3.649	2.622	1.267	0.172	3,879
Nervous system	71.738	13.267	1.588	1.562	0.384	679
Digestive and excretory system	67.029	17.231	2.137	0.984	0.155	27,005
Lean of head and tail	67.242	12.739	3.042	0.969	0.166	3,036
Lean of shin and shank	71.639	5.602	3.208	0.957	0.172	11,828
Lean of round	72.787	5.779	3.204	1.031	0.188	39,952
Lean of rump	68.201	10.956	3.122	0.945	0.180	4,878
Lean of flank	64.311	14.658	3.108	0.948	0.177	4,026
Lean of loin	67.736	11.540	3.068	0.947	0.186	30,662

TABLE 46.—PERCENTAGE COMPOSITION OF SAMPLES OF STEER 197—Continued

Sample	Per cent water	Per cent fat	Per cent nitrogen	Per cent ash	Per cent phosphorus	Weight grams
Lean of chuck and neck.....	70.538	9.227	3.105	0.967	0.175	54,452
Lean of plate	61.623	19.809	2.740	0.861	0.158	18,678
Lean of rib	65.473	14.890	3.042	0.885	0.169	16,156
Fat of head and tail.....	41.947	45.765	2.258	0.626	0.091	1,034
Fat of shin and shank	29.006	57.401	2.026	0.340	0.036	2,934
Fat of round	25.272	65.995	1.616	0.301	0.040	10,110
Fat of rump	16.292	77.184	0.833	0.209	0.029	3,612
Fat of flank	19.489	73.175	1.219	0.206	0.028	6,430
Fat of loin	15.585	79.721	0.771	0.203	0.030	12,438
Fat of chuck and neck	25.031	67.083	1.364	0.280	0.044	11,546
Fat of plate	19.095	75.329	0.888	0.225	0.027	15,304
Fat of rib	23.468	68.470	1.221	0.314	0.042	5,854
Offal fat	14.342	83.624	0.402	0.151	0.023	11,028
Kidney fat	7.049	90.820	0.381	0.136	0.019	2,302
Bone of feet	38.787	14.285	3.861	23.564	3.693	7,050
Bone of head and tail	44.860	10.821	3.134	23.388	4.311	8,439
Bone of shin and shank.....	28.683	23.318	3.190	26.922	4.592	11,640
Bone of round	23.877	32.640	2.682	25.019	5.070	6,054
Bone of rump	27.327	30.164	2.908	23.851	4.190	3,164
Bone of loin	25.647	31.281	3.030	23.922	3.846	7,494
Bone of chuck and neck.....	31.287	22.985	3.121	25.342	4.298	14,964
Bone of plate and flank.....	41.483	17.553	3.222	19.474	3.159	5,988
Bone of rib	29.595	22.881	3.100	26.570	4.419	5,512
Teeth	24.263	0.928	2.022	57.773	11.232	754
Horns	42.746	0.533	6.117	19.279	3.669	1,316
Hoofs and dew claws.....	56.455	0.752	7.114	0.963	0.095	1,787

TABLE 47.—WEIGHT OF CONSTITUENTS IN PARTS ANALYZED, STEER 18

Parts	Total grams	Water grams	Fat grams	Nitrogen grams	Ash grams	Phosphorus grams
Blood	15,599	12,680.4	66.9	453.8	107.3	3.43
Hair and hide	25,674	16,781.8	740.2	1,308.3	222.9	17.46
Skeleton	58,261	16,483.2	14,723.7	1,760.7	14,755.2	2,842.57 ²
Circulatory system	2,594	1,465.6	780.0	51.8	19.5	3.19
Respiratory system	3,079	2,300.3	198.9	84.9	29.5	4.65
Nervous system	722	487.0	127.3	12.6	12.7	3.05
Digestive and excretory system ¹	18,436	12,261.8	3,342.1	385.9	301.2	23.78
Liver	2,625	1,811.0	91.1	79.4	32.9	8.16
Kidneys	762	571.8	66.6	18.1	8.3	1.61
Lean and fat of shin, shank, head and tail	12,106	8,163.4	1,451.5	389.7	93.3	17.55
Lean and fat of round and rump	38,258	25,442.7	5,072.2	1,189.8	337.8	65.80
Lean and fat of loin.....	27,152	16,264.0	5,897.1	778.2	214.0	42.64
Lean and fat of flank and plate	21,810	11,452.4	6,565.5	532.2	141.6	27.04
Lean and fat of rib.....	13,760	8,639.9	2,481.9	423.3	113.0	22.15
Lean and fat of chuck and neck	44,008	29,256.5	6,191.0	1,328.6	360.0	67.77
Offal fat	5,700	947.3	4,543.9	29.5	9.8	1.54
Kidney fat	2,444	245.4	2,125.4	10.3	2.9	0.51
Teeth	682	149.7	3.1	14.1	418.2	78.85
Horns, hoofs, dew claws	1,346	689.3 ³	10.3	103.6	30.4	2.01

¹Less the liver and kidneys.²4.879 per cent phosphorus was assumed to be more normal than 2.879 per cent.³Average analysis of four similar thin animals was used for this sample.

TABLE 48.—WEIGHTS OF CONSTITUENTS IN PARTS ANALYZED, STEER 121

Parts	Total grams	Water grams	Fat grams	Nitro- gen grams	Ash grams	Phos- phorus grams
Blood	24,433	19,050.7	.....	795.3	60.6	6.84
Hide and hair	29,662	17,727.2	1,473.9	1,641.5	224.8	16.61
Skeleton	66,391	19,686.9	14,064.9	2,323.7	17,997.3	3,190.75
Circulatory system ¹	2,677	734.0	1,747.4	25.5	5.5	1.04
Lean heart	1,596	1,235.0	70.1	41.0	16.0	3.37
Respiratory system	4,631	2,961.8	911.9	106.9	37.4	7.87
Nervous system	710	485.3	138.4	11.9	11.1	2.80
Digestive and excretory system ²	15,525	8,621.8	4,925.3	250.1	98.3	19.56
Tongue, marketable	1,862	1,124.6	470.6	41.4	12.0	2.46
Stomachs	14,253	11,154.4	1,170.0	251.4	138.4	28.51
Liver	7,035	4,809.1	331.8	224.5	92.3	24.83
Kidneys	1,098	840.9	61.1	30.1	10.4	2.51
Lean and fat of shin, shank, head and tail	18,516	11,534.5	3,366.8	542.3	135.7	26.29
Lean of round and rump	47,782	33,429.7	3,910.0	1,568.7	457.3	91.26
Fat of round and rump	13,924	2,006.5	11,223.4	85.9	21.3	4.18
Lean of loin	33,686	22,643.7	3,838.9	1,013.3	317.7	62.32
Fat of loin	20,458	1,856.6	17,970.3	81.0	27.2	4.91
Loin and fat of flank and plate....	55,862	22,385.6	26,646.7	1,074.8	279.3	53.07
Lean of rib	21,240	12,952.2	4,433.6	591.8	165.0	32.50
Fat of rib	7,458	796.3	6,416.5	33.8	10.1	2.01
Lean and fat of chuck and neck	69,456	41,077.0	16,964.6	1,809.3	487.6	98.63
Kidney fat	7,272	326.1	6,884.4	13.2	5.1	0.87
Offal fat	27,376	2,605.4	24,095.0	74.7	35.3	6.02
Teeth	556	63.4	3.4	13.4	384.9	76.80
Hoofs and dew claws.....	1,480	656.3 ³	12.4	129.9	33.2	2.60

¹Less the lean heart.²Less the tongue, stomachs, liver, and kidneys.³The average analysis of three similar animals was used for this sample.

TABLE 49.—WEIGHTS OF CONSTITUENTS IN PARTS ANALYZED, STEER 48

Blood	25,634	20,356.0	.....	809.5	198.7	5.38
Hide and hair	41,164	24,385.6	3,540.1	2,185.0	492.7	19.76
Circulatory system ¹	4,207	423.6	3,721.1	12.0	6.1	1.09
Heart, marketable	2,573	1,693.8	500.5	54.7	21.5	4.07
Respiratory system	10,970	5,421.4	4,101.7	214.7	73.4	12.83
Nervous system	774	538.9	101.0	16.2	14.0	3.29
Digestive and excretory system ²	14,059	9,020.3	3,150.6	250.0	98.0	18.00
Tongue, marketable	2,376	1,331.0	700.9	54.0	17.7	2.99
Stomachs	14,113	10,549.5	1,685.1	248.0	151.4	32.04
Liver	8,166	5,694.2	347.9	236.2	113.7	25.07
Kidneys	1,227	868.1	149.2	30.0	14.2	2.44
Lean and fat of shin, shank, head and tail	19,494	11,275.3	4,575.2	556.2	161.6	27.68
Lean and fat of rump.....	16,086	5,937.3	8,472.5	255.3	81.9	14.96
Lean of round	50,284	32,398.0	6,748.1	1,648.3	510.4	96.55
Fat of round	19,520	5,416.8	13,146.7	149.3	49.0	5.27
Lean of loin	43,154	26,660.5	7,879.9	1,286.4	412.6	75.09
Fat of loin	43,826	5,522.1	37,146.9	186.7	64.0	10.08
Lean and fat of flank and plate	91,206	27,498.6	55,736.0	1,193.0	384.0	58.37
Lean of rib	24,260	13,788.6	6,011.6	649.7	200.6	36.38

TABLE 49.—WEIGHTS OF CONSTITUENTS IN PARTS ANALYZED, STEER 48—Continued

Parts	Total grams	Water grams	Fat grams	Nitro- gen grams	Ash grams	Phos- phorus grams
Fat of rib	27,010	4,270.3	21,978.0	116.4	41.9	5.67
Lean and fat of chuck and neck	106,952	53,123.1	37,379.7	2,424.6	741.2	131.55
Offal fat	61,837	3,846.3	56,945.7	112.5	57.5	7.42
Kidney fat	17,170	645.6	16,261.7	41.0	21.6	2.75
Bone of head, tail, and feet.....	17,559	6,505.6	2,022.6	602.1	4,303.7	813.86
Bone of shin and shank	12,532	2,595.4	3,050.8	401.3	4,140.6	773.60
Bone of flank and plate.....	6,936	2,617.0	1,357.2	208.0	1,402.5	261.63
Bone of chuck and neck.....	16,142	4,484.3	3,011.3	569.3	4,443.9	818.88
Bone of round	6,318	1,463.3	2,052.0	134.2	1,710.3	317.16
Bone of rump	3,520	925.4	1,256.2	80.8	726.9	136.96
Bone of loin	9,368	2,018.8	2,773.2	264.2	2,444.1	450.13
Bone of rib	7,294	1,951.2	1,339.1	240.9	2,145.2	395.04
Teeth	712	181. ⁶⁰	7.5	13.6	414.5	79.13
Hoofs and dew claws	1,675	742. ⁷⁴	14.0	147.0	37.6	2.95

¹Less the marketable heart.²Less the tongue, stomachs, liver, and kidneys.³The average analysis of four similar animals was used for this sample.⁴The average analysis of three similar animals was used for this sample.

TABLE 50.—WEIGHTS OF CONSTITUENTS IN PARTS ANALYZED, STEER 197

Blood	20,067	15,799.0	.....	654.2	132.4	5.22
Hide and hair	35,209	21,580.7	1,721.0	1,921.0	328.9	1.76
Circulatory system	3,806	2,074.4	1,242.2	68.8	31.3	4.45
Respiratory system	3,879	3,039.3	141.5	101.7	49.2	6.67
Nervous system	679	487.1	90.1	10.8	10.6	2.61
Digestive and excretory system.....	27,005	18,101.2	4,653.2	577.1	265.7	41.86
Lean of head and tail.....	3,036	2,041.5	386.8	92.4	29.4	5.04
Lean of shin and shank	11,828	8,473.5	662.6	379.4	113.2	20.34
Lean of round	39,952	29,079.9	2,308.8	1,280.1	411.9	75.11
Lean of rump	4,878	3,326.8	534.4	152.3	46.1	8.78
Lean of flank	4,026	2,589.2	590.1	125.1	38.2	7.13
Lean of loin	30,662	20,769.2	3,538.4	940.7	290.4	57.03
Lean of chuck and neck.....	54,452	38,409.4	5,024.3	1,690.7	526.6	95.29
Lean of plate	18,678	11,509.9	3,699.9	511.8	160.8	29.51
Lean of rib	16,156	10,577.8	2,405.6	491.5	143.0	27.30
Fat of head and tail	1,034	433.7	473.2	23.4	6.5	0.94
Fat of shin and shank.....	2,934	851.0	1,684.2	59.4	10.0	1.06
Fat of round	10,110	2,555.0	6,672.1	163.4	30.4	4.04
Fat of rump	3,612	588.5	2,787.9	30.1	7.6	1.05
Fat of flank	6,430	1,253.1	4,705.2	78.4	13.3	1.80
Fat of loin	12,438	1,938.5	9,915.7	95.9	25.3	3.73
Fat of chuck and neck	11,546	2,890.1	7,745.4	157.5	32.3	5.08
Fat of plate	15,304	2,922.3	11,528.4	135.9	34.4	4.13
Fat of rib	5,854	1,373.8	4,008.2	71.5	18.4	2.46
Offal fat	11,028	1,581.6	9,222.1	44.3	16.7	2.54
Kidney fat	2,302	162.3	2,090.7	8.8	3.1	0.44
Bone of feet	7,050	2,734.5	1,007.1	272.2	1,661.3	260.36
Bone of head and tail.....	8,439	3,785.7	913.2	264.5	1,973.7	363.80
Bone of shin and shank	11,640	3,338.7	2,714.2	371.3	3,133.7	534.51
Bone of round	6,054	1,445.5	1,976.0	162.4	1,514.7	306.94
Bone of rump	3,164	864.6	954.4	92.0	754.7	132.57
Bone of loin	7,494	1,922.0	3,344.2	227.1	1,792.7	288.22
Bone of chuck and neck	14,964	4,681.8	3,439.5	467.0	3,792.2	643.15
Bone of plate and flank.....	5,988	2,484.0	1,051.1	192.9	1,166.1	189.16
Bone of rib	5,512	1,631.3	1,261.2	170.9	1,464.5	243.58
Teeth	754	182.9	7.0	15.3	435.6	84.69
Horns	1,316	562.5	7.0	80.5	253.7	48.28
Hoofs and dew claws	1,787	1,008.9	13.4	127.1	17.2	1.70

PREPARATION AND ANALYSIS OF SAMPLES

As soon as the skeleton samples could be prepared they were run thru a Mann bone grinder and mixed well. A sample was taken and sent to the chemical laboratory. The lean and fat and offal samples were run thru a power grinder equipped with four plates, each containing different sized holes. Samples were ground thru the coarser plate and then thru the next size. The samples were well mixed and quartered if necessary, and then ground through a finer plate. The large samples were then quartered again and ground thru the finest plate. Very homogeneous and fine samples were easily obtained in this manner. An especially difficult sample to make uniform and representative was that of the respiratory system. The cartilaginous rings of the trachea would partly remain behind in the grinder while the softer lungs were squeezed out past them. By using a knife and by careful work these were cut fine and mixed with the lungs.

Details of the methods of analysis can not be given here but will appear in a later publication. Moisture was determined in vacuum desiccators and the residue was extracted with ether to determine the fat. Vacuum only was used for this work. Nitrogen was run by the modified Kjeldahl-Gunning method. Ash was determined by ignition in porcelain crucibles and phosphorus was determined in the residue by the usual gravimetric method.

The work of preparing and grinding the samples was conducted as rapidly as possible until the samples were in a position where there was no danger of decomposition. The samples were kept in sample jars provided with rubber gaskets, glass tops and metal clamps so that no loss of moisture could occur. They were kept in cold storage at a temperature just above freezing, so that they remained fresh for analysis. An outline of the program for slaughtering week will illustrate this. The animal was killed Monday morning. The offal samples were ground, sampled and started on the analysis that afternoon and the following day. The chemical and slaughter house force always worked during the nights, so that by Wednesday noon the offal samples were safe. On Wednesday the carcass was cut up, the separations and composites were made, and the grinding of samples was begun. By the end of the week, all analyses were well on their way and the rush work was over.

METHOD OF ANALYSIS FOR BONE SAMPLES

Samples for moisture were weighed out directly and rapidly, in triplicate, in tared porcelain evaporating dishes. The size of the sample varied according to the coarseness or fineness of the bone. For finely ground samples 25 to 40 grams were considered sufficient while for coarse samples 100 grams or even more were sometimes taken. The dishes containing the weighed samples were at once placed in vacuum desiccators and dried as in the moisture determination. The dish and dry bone were weighed rather rapidly in the open and the drying was continued until the loss in weight at successive weighings was less than 25 or 30 milligrams.

The dry samples from the foregoing determinations were transferred carefully to Soxhlet extractors having a disk of hard filter paper in the bottom for filtering the ether extract. Redistilled anhydrous ether was used for the extraction and the extract was collected in weighed flasks. The extraction was continued for thirty hours. The ether was distilled off and saved and the flasks were dried for twenty hours in vacuo and weighed.

The residue from the extraction was saved, the triplicates were combined and the whole was ground in a steel mill until fine enough to pass thru a millimeter mesh sieve. This air dry sample was kept for further determinations of moisture, fat, nitrogen, ash, and phosphorus.

COMPOSITION OF SAMPLES, PARTS, AND TOTAL ANIMAL

A brief discussion of the composition of the samples follows. Many comparisons can be made, but here only certain striking results will be emphasized.

Blood.—The blood of the maintenance steer, Steer 18, was higher in moisture content than the blood of the other three animals. The fattest old steer, Steer 48, ranked next, then the old maintenance steer, followed by the three-year-old prime steer, Steer 121. This order is not vital. The blood of Steer 18 contained 0.4 per cent of fat. This might have been due to incomplete drying of the sample. In none of the blood samples subsequently analyzed was found any ether extract. The steers had all been fed the morning of slaughtering and were killed approximately the same length of time after eating. The protein content varied inversely as the moisture, and ran from 18 to 20.4 per cent. The ash varied from 0.66 to 0.77 per cent in three animals. The low percentage in Steer

121 was unaccountable. The phosphorus was about constant at 0.02 to 0.03 per cent.

Hide and hair.—The hide and hair were noticeably high in moisture and protein. The latter was one-third and the former 60 per cent or more of the total. The moisture content decreased while the dry substance increased with the increasing fatness of the steers. The fat content increased directly with the increasing fatness of the steers. The order of the steers in this respect was: 18, 197, 121, and 48. The protein content of the fresh hide was about constant. However, on a moisture-free basis, the protein found in the different hides was: Steer 18, 91.959 per cent; Steer 197, 88.098 per cent; Steer 121, 85.968 per cent; and Steer 48, 81.391 per cent. These figures indicate a decrease in protein with increasing fatness. The ash and phosphorus content was low. The ash was fairly constant, while the phosphorus varied without order.

Skeleton.—The skeletons of the four animals were fairly constant in composition, except in the phosphorus of Steer 18, the data for which is unreliable, and the moisture of Steer 197 which was 3 per cent higher than any of the others. The moisture was about 30 per cent, the fat and protein 20 to 25 per cent, the ash 25 per cent, and the phosphorus from 4 to 5 per cent, of the total skeleton. The composition of the skeleton seems to have been practically independent of the condition of the animal.

Circulatory system.—The circulatory systems decreased very markedly in water content and increased in fat content as the steers increased in fatness. Sixty-two per cent of the system in Steer 48 was fat. This shows to what extent fat was laid on around the pericardium. The protein, ash, and phosphorus decreased relatively as the fat increased, altho the actual quantity increased with increasing weight of animal. The moisture constituted one-third to one-half of the system, the fat 30 to 60 per cent, and the protein 6 to 12 per cent.

Respiratory system.—The respiratory systems varied as the circulatory systems, but they contained relatively less fat and more protein.

Nervous system.—The nervous systems were fairly constant in composition, except in fat. In the case of Steer 18 and Steer 121 the sheath and fat surrounding the spinal cord were removed with the cord. The cord alone was separated in all subsequent cases. This accounts for the increased fat found in the two animals.

Digestive and excretory system.—The total digestive and excretory system was constant in composition for all four animals, and

contained 67 to 68 per cent moisture, 15 to 17 per cent fat, 13 to 14 per cent protein, 1 to 1.5 per cent ash, and 0.15 to 0.20 per cent phosphorus. It must be remembered that the fat had been stripped off this system and the composition represented the lean organs. The higher percentage of fat in the case of Steer 121 may easily have been due to a difference in the mechanical separation in the slaughter house. The liver was constant in composition, with 70 per cent of moisture and 20 per cent of protein. The kidneys also were fairly constant in composition, altho those of Steer 48 contained 4 per cent less moisture and a larger per cent of fat than the other animals. This may have been due to differences in the removal of the kidney fat from the helix of the organ. The kidneys contained 75 per cent moisture and 15 per cent protein.

Offal and kidney fat.—In the offal and kidney fat the fat increased with the fatness of the steers, while the other constituents decreased. The kidney fat contained a greater percentage of fat than the offal fat. Eighty to 95 per cent of these samples was fat.

The flesh samples were not all subjected to the same division. The lean and fat samples of Steer 197 were analyzed separately. In all the samples the per cent of fat increased while the per cent of the other substances decreased with increasing fatness of the steers. A fat cut, such as the lean and fat of the flank and plate, may be 30 to 60 per cent fat.

In the foregoing discussion the percentage composition has been considered. From these per cents and the weight of the sample the weights of the different constituents in each sample have been calculated. Tables 47 to 50 give the results. These weights have been used to calculate the composition of certain parts and of the total animal. Tables 51 to 54 give the results.

The sum of the various parts analyzed did not equal the warm empty weight of the animal at slaughter. Later records have shown that most of this loss was due to cooling and drying out of the carcass between the day of slaughter and the day of cutting. Consequently the difference was credited entirely to moisture and it was added to the weight of water found by analysis to get the composition of the total warm empty animal.

TABLE 51.—COMPOSITION OF CERTAIN PARTS AND OF THE TOTAL ANIMAL, STEER 18

Parts	Weight of parts in grams	Per cent. water	Weight water	Per cent. fat	Weight fat	Per cent. nitro-gen	Weight nitro-gen	Per cent. protein	Weight protein	Per cent. ash	Weight ash	Per cent. phosphorus	Weight phosphorus
Lean and fat flesh.....	159538	62.345	99464.3	18.669	29784.6	2.916	4652.1	18.225	29075.0	0.791	1262.6	0.153	243.46
Skeleton	58261	28.292	16483.2	25.272	14723.7	3.022	1760.7	18.888	11004.8	25.326	14755.2	4.879	2842.57 ¹
Hair and hide.....	25674	65.365	16781.8	2.883	740.2	5.096	1308.3	31.850	8176.9	0.868	222.9	0.068	17.46
Teeth	682	21.947	149.7	0.461	3.1	2.061	14.1	12.881	88.1	61.324	418.2	11.562	78.85
Horns, hoofs and dew claws ²	1346	51.207	689.3	0.768	10.3	7.694	103.6	48.088	647.5	2.256	30.4	0.149	2.01
Offal fat	5700	16.620	947.3	79.718	4543.9	0.517	29.5	3.231	184.4	0.172	9.8	0.027	1.54
Blood	15599	81.290	12680.4	0.429	66.9	2.909	453.8	18.181	2836.3	0.688	107.3	0.022	3.43
Circulatory system.....	2594	56.503	1465.6	30.068	780.0	1.996	51.8	12.475	323.8	0.751	19.5	0.123	3.19
Respiratory system	3079	74.710	2300.3	6.461	198.9	2.756	84.9	17.225	530.6	0.959	29.5	0.151	0.47
Nervous system	722	68.830	487.0	17.625	127.3	1.750	12.6	10.938	78.8	1.757	12.7	0.422	3.05
Digestive and excretory system	21823	67.106	14644.7	16.037	3499.7	2.215	483.4	13.844	3021.3	1.569	342.4	0.154	33.55
Total parts	295018	56.298	166093.6	18.466	54478.6	3.035	8954.8	18.969	55967.5	5.834	17210.5	1.095	3229.58
Loss on cooling and cutting	7165	.....	7165	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total warm empty animal	302183	57.336	173258.6	18.028	54478.6	2.963	8954.8	18.519	55967.5	5.695	17210.5	1.069	3229.58

¹See note to Table 47 concerning this data.²Average analysis of four similar samples was used here on account of loss of this sample.

TABLE 52.—COMPOSITION OF CERTAIN PARTS AND OF THE TOTAL ANIMAL, STEER 121

Parts	Weight of parts grams	Per ct. water	Weight water	Per ct. fat	Weight fat	Per ct. nitro- gen	Weight nitro- gen	Per ct. protein	Weight protein	Per ct. ash	Weight ash	Per ct. phos- phorus	Weight phos- phorus
Lean and fat flesh.....	295684	50.400	149008.2	34.383	101655.2	2.305	6814.1	14.406	42588.1	0.645	1906.3	0.127	376.04
Skeleton	66391	29.653	19686.9	21.185	14064.9	3.500	2323.7	21.875	14523.1	27.108	17997.3	4.806	3190.74
Hair and hide	29662	59.764	17727.2	4.969	1473.9	5.534	1641.5	34.590	10259.4	0.758	224.8	0.056	16.61
Teeth	556	11.401	63.4	0.618	3.4	2.410	13.4	15.063	83.8	69.227	384.9	13.813	76.80
Hoofs and deys claws ¹	1480	44.341	656.3	0.836	12.4	8.775	129.9	54.844	811.9	2.245	33.2	0.176	2.60
Offal fat	27376	9.517	2605.4	88.105	24095.0	0.273	74.7	1.710	466.9	0.129	35.3	0.022	6.02
Blood	24433	77.971	19050.7	.....	.....	3.255	795.3	20.340	4970.6	0.248	60.6	0.028	6.84
Circulatory system	4273	46.081	1969.1	42.534	1817.5	1.558	66.6	9.738	416.3	0.502	21.5	0.103	4.41
Respiratory system	4631	63.955	2961.8	19.692	911.9	2.308	106.9	14.430	668.1	0.808	37.4	0.170	7.87
Nervous system	710	68.357	485.3	19.499	138.4	1.676	11.9	10.480	74.4	1.502	11.1	0.395	2.80
Digestive and excretory system	39773	66.756	26550.8	17.496	6958.7	2.005	797.5	12.531	4984.4	0.883	351.4	0.196	77.87
Total parts	494939	48.645	240765.1	30.535	151131.3	2.581	12775.5	16.131	79846.9	4.256	21063.8	0.761	3768.60
Loss on cooling and cutting	13574	.....	13574	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total warm empty animal	508513	50.016	254339.1	29.720	151131.3	2.512	12775.5	15.700	79846.9	4.142	21063.8	0.741	3768.60

¹Average analysis of three similar samples was used here on account of loss of this sample.

TABLE 53.—COMPOSITION OF CERTAIN PARTS AND OF THE TOTAL ANIMAL, STEER 48

Parts	Weight of parts grams	Per ct. water	Weight water	Per ct. fat	Weight fat	Per ct. nitro- gen	Weight nitro- gen	Per ct. protein	Weight protein	Per ct. ash	Weight ash	Per ct. phos- phorus	Weight phos- phorus
Lean and fat flesh.....	458952	40.644	186536.2	46.919	215336.3	1.854	8506.9	11.588	53168.1	0.581	2668.8	0.101	464.35
Skeleton	79669	28.318	22560.8	21.166	16862.4	3.139	2500.8	19.619	15630.0	26.757	21317.1	4.980	3967.27
Hair and hide	41164	52.905	24385.6	8.600	3540.1	5.308	2185.0	33.175	13656.3	1.197	492.7	0.048	19.76
Teeth ¹	712	25.508	181.6	1.052	7.5	1.906	13.6	11.913	85.0	58.218	414.5	11.114	79.13
Hoofs and dew claws ²	1675	44.341	742.7	0.836	14.0	8.775	147.0	54.844	918.8	2.245	37.6	0.176	2.95
Offal fat	61837	6.220	3846.3	92.090	56945.7	0.182	112.5	1.138	703.1	0.093	57.5	0.012	7.42
Blood	25634	79.410	20356.0	.....	.....	3.158	809.5	19.738	5059.4	0.775	198.7	0.021	5.38
Circulatory system	6780	31.231	2117.4	62.265	4221.5	0.983	66.7	6.144	416.9	0.407	27.6	0.076	5.16
Respiratory system	10970	49.420	5421.4	37.390	4101.7	1.957	214.7	12.231	1341.9	0.665	73.4	0.117	12.83
Nervous system	774	69.630	538.9	13.050	101.0	2.093	16.2	13.081	101.3	1.813	14.0	0.425	3.29
Digestive and excretory system	39941	68.759	27463.0	15.107	6033.7	2.049	818.2	12.806	5113.5	0.989	394.9	0.202	80.54
Total parts	728108	40.396	294149.9	42.187	307163.9	2.114	15391.1	13.213	96194.4	3.529	25696.8	0.638	4648.08
Loss on cooling and cutting	16600	.....	16600	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total warm empty animal	744708	41.728	310749.9	41.246	307163.9	2.067	15391.1	12.919	96194.4	3.451	25696.8	0.624	4648.08

¹Average analysis of five similar samples was used here on account of loss of this sample.²Average analysis of three similar samples was used here on account of loss of this sample.

TABLE 54.—COMPOSITION OF CERTAIN PARTS AND OF THE TOTAL ANIMAL, STEER 197

Parts	Weight of parts grams	Per ct. water	Weight water	Per ct. fat	Weight fat	Per ct. nitro-gen	Weight nitro-gen	Per ct. protein	Weight protein	Per ct. ash	Weight ash	Per ct. phosphorus	Weight phosphorus
Lean and fat flesh ...	255232	55.536	141745.5	27.725	70761.9	2.542	6488.3	15.888	40551.9	0.760	1940.9	0.137	350.26
Skeleton	70305	32.555	22888.1	22.276	15660.9	3.158	2220.3	19.738	13876.9	24.541	17253.5	4.213	2962.28
Hair and hide	35209	61.293	21580.7	4.888	1721.0	5.456	1921.0	34.100	12006.3	0.934	328.9	0.050	1.76
Teeth	74	24.263	182.9	0.928	7.0	2.022	15.3	12.638	95.6	57.773	435.6	11.232	84.69
Horns	1316	42.746	562.5	0.533	7.0	6.117	80.5	38.231	503.1	19.279	253.7	3.669	48.28
Hoofs and dew claws	1787	56.455	1008.9	0.752	13.4	7.114	127.1	44.463	794.4	0.963	17.2	0.095	1.70
Offal fat	11028	14.342	1581.6	83.624	9222.1	4.402	44.3	2.513	276.9	0.151	16.7	0.023	2.54
Blood	20067	78.731	15799.0	.....	.....	3.260	654.2	20.375	4088.8	0.660	132.4	0.026	5.22
Circulatory system ...	3806	54.502	2074.4	32.638	1242.2	1.807	68.8	11.294	430.0	0.822	31.3	0.117	4.45
Respiratory system ...	3879	78.352	3039.3	3.649	141.5	2.622	101.7	16.388	635.6	1.267	49.2	0.172	6.67
Nervous system	679	71.738	487.1	13.267	90.1	1.588	10.8	9.925	67.5	1.562	10.6	0.384	2.61
Digestive and excretory system ...	27005	67.029	18101.2	17.231	4653.2	2.137	577.1	13.356	3606.9	0.984	265.7	0.155	41.86
Total parts	431067	53.136	229051.2	24.015	103520.3	2.856	12309.4	17.850	76933.8	4.810	20735.7	0.815	3512.32
Loss on cooling and cutting	13683	.....	13683	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total warm empty animal	444750	54.578	242734.2	23.276	103520.3	2.768	12309.4	17.300	76933.8	4.562	20735.7	0.790	3512.32

A detailed discussion of the effects of fattening versus a long maintenance period upon the composition of the various divisions shown would lead to the same conclusion arrived at from an inspection of Table 55. This table shows that as the animals became fatter the per cents of dry substance and fat increased with the increasing fatness, and all other constituents decreased.

TABLE 55.—COMPOSITION OF THE ANIMALS

	Per cent water	Per cent fat	Per cent nitrogen	Per cent protein	Per cent ash	Per cent ph'sph'r's
Steer 18, very thin.....	57.336	18.028	2.963	18.519	5.695	1.069
Steer 197, medium	54.578	23.276	2.768	17.300	4.662	0.790
Steer 121, half fat.....	50.016	29.720	2.512	15.700	4.142	0.741
Steer 48, very fat.....	41.728	41.246	2.067	12.919	3.451	0.624

In addition to the increasing amount of fat, the fattening of a steer has an effect upon the quality of the fatty tissue and of the pure fat itself. Tables 56 to 61 show the analysis of a number of fat samples from six of the animals, together with some of the more important physical constants of the pure fat. Fattening increased the per cent of fat in the fatty tissue of the body in addition to increasing the amount of fatty tissue. From these experiments it is evident that this increase in per cent of fat, and decrease in per cent of water and protein, followed the order of increasing fatness of the animals. The fat deposited became softer as shown by the increased iodine absorption number and lower melting point for the same sample of fat.

TABLE 56.—ANALYSIS OF SPECIAL FAT SAMPLES, STEER 18

Samples	Per cent water	Per cent fat	Per cent nitrogen	Iodine value	Melting point	Saponification number
Kidney fat	10.044	86.962	0.421	33.41	47.40	197.70
Offal fat	16.620	79.718	0.517	33.97	48.58	198.80
Inside chuck fat.....	25.055	68.797	3.952	45.88	41.75	196.70
Outside rump fat	14.315	80.630	0.782	43.22	41.65	190.70
Outside rib fat	25.265	66.297	1.174	51.64	38.38	200.20
Outside chuck fat	23.280	69.550	1.036	46.68	38.95	199.10

TABLE 57.—ANALYSIS OF SPECIAL FAT SAMPLES, STEER 121

Samples	Per cent water	Per cent fat	Per cent nitrogen	Iodine value	Melting point	Saponification number
Kidney fat	4.484	94.670	0.181	40.84	45.05	197.00
Offal fat	9.517	88.015	0.273	38.39	45.20	195.80
Loin fat	9.075	87.840	0.396	43.64	41.95	193.30
Inside chuck fat	11.213	86.843	0.312	46.90	40.50	197.96
Cod fat	17.920	78.510	0.466	46.67	39.85	199.50
Rib fat	10.677	86.035	0.453	45.18	40.30	198.80
Fat between hind legs....	7.204	90.640	0.307	44.83	39.65	201.10
Round and rump fat.....	14.410	80.605	0.617	46.32	39.60	194.30
Outside rump fat	10.870	86.560	0.396	49.29	35.25	195.70
Outside rib fat	29.255	64.720	0.348	54.25	35.55	180.60

TABLE 58.—ANALYSIS OF SPECIAL FAT SAMPLES, STEER 48

Samples	Per cent water	Per cent fat	Per cent nitrogen	Iodine value
Kidney fat	3.76	94.71	0.239	40.64
Offal fat	6.22	92.09	0.182	.....
Marrow, humerus	5.99	93.29	0.117	.....
Outside rump fat	16.04	81.81	0.452	58.37
Cod fat	27.11	71.37	0.188	.....
Brisket fat	25.76	71.80	0.331	.....
Outside round fat	14.60	81.78	0.587	.....
Plates inside rib	5.40	92.71	0.323	.....
Outside 10th rib outer	15.20	83.81	0.244	.....
Outside 10th rib inner	24.70	73.38	0.189	.....
Tenth rib intramuscular	4.60	94.89	0.116	.....

TABLE 59.—ANALYSIS OF SPECIAL FAT SAMPLES, STEER 164

Samples	Per cent water	Per cent fat	Per cent nitrogen
Kidney fat	5.278	93.124	0.225
Scrotum, Aug. 9, 1909	31.730	64.106	0.485
Cod fat	26.857	67.499	0.438
Rump fat	8.943	88.290	0.459
Roll over rib	9.157	87.908	0.359
Outside rib	9.587	87.581	0.414
Rib intramuscular	8.427	89.541	0.288
Inside rib plates	8.597	89.550	0.263
Outside of crops	12.693	83.628	0.539
Inside chuck	20.545	75.909	0.796
Brisket	30.984	61.169	1.285

TABLE 60.—ANALYSIS OF SPECIAL FAT SAMPLES, STEER 197

Samples	Per cent water	Per cent fat	Per cent nitrogen
Kidney fat	7.049	90.820	0.381
Offal fat	14.342	83.624	0.402
Outside 10th rib outer	21.707	71.717	0.986
Outside 10th rib inner	23.525	71.214	0.727
Cod fat	12.496	82.293	0.401
Inside chuck	19.244	74.880	0.810
Brisket	17.833	80.703	0.499
Outside rump	19.482	74.389	0.966
Plates inside rib	8.073	88.219	0.591
Outside over crops	12.408	83.643	0.661

TABLE 61.—ANALYSIS OF SPECIAL FAT SAMPLES, STEER 588

Samples	Per cent water	Per cent fat	Per cent nitrogen	Iodine value
Kidney fat	8.993	89.122	0.289	43.687
Brisket	21.421	74.582	0.663	.....
Caul	10.631	87.262	0.306	.....
Cod	14.176	82.945	0.350	.....
Rump	18.987	75.515	0.676	67.65
Outside rib, outer layer	22.434	72.213	0.784	.....
Outside rib, inner layer	13.203	83.848	0.493	.....
Roll back of last rib	14.713	80.988	0.536	.....

COMPOSITION OF WEIGHT GAINED

The composition of the flesh gained in developing from a thin to half fat and very fat condition can easily be calculated for three of the animals. Steers 18, 121, and 48 were very much alike in type, breed, age, and method of treatment. The composition of Steer 18 at slaughter serves as the basis for the computation. It is assumed that all three animals had the same composition while they were thin maintenance animals.

Since Steer 121 during maintenance, or at the beginning of the full-fed period, weighed less than the check animal and Steer 48 weighed more, it is necessary to calculate their composition at this different weight. At slaughter Steer 18 weighed 342.687 kilos. Its warm empty weight was 302.183 kilos. This was 85.62 per cent of the live weight during the last ten days of maintenance. At this per cent the warm empty weight of Steer 121 would have been 296.787 kilos and that of Steer 48 would have been 326.808 kilos. At the close of maintenance then Steer 121 weighed 5.396 kilos less than Steer 18, and Steer 48 weighed 24.625 kilos more than Steer 18.

TABLE 62.—CALCULATED COMPOSITION OF GAIN MADE BY STEER 121 OVER STEER 18

	At be- ginning grams	At end, grams	Weight gained, grams	Composi- tion of gain, per cent
Warm empty weight	296,787.0	508,513.0	211,726.0	.....
Water	170,164.7	254,339.1	84,174.4	39.756
Fat	53,505.8	151,131.3	97,625.5	46.109
Nitrogen	8,794.9	12,775.5	3,980.6	1.880
Protein	54,968.1	79,846.9	24,878.8	11.750
Ash	16,903.2	21,063.8	4,160.6	1.965
Phosphorus	3,171.9	3,768.6	596.7	0.282

Taking the analysis of Steer 18 as representing all three steers at the end of maintenance, the amounts of water, fat, protein, ash, and phosphorus in Steer 121 and Steer 48 at that time can be calculated. Tables 62 and 63 show the results. The flesh gained by the steers in developing from a thin condition to the condition 40 to 50 days under prime contained nearly 40 per cent water, more than 46 per cent fat, and less than 12 per cent protein. In developing to the very fat or prime condition the gains made contained less than 30 per cent water, more than 59 per cent fat, and about 8.5 per cent protein.

TABLE 63.—CALCULATED COMPOSITION OF GAIN MADE BY STEER 48 OVER STEER 18

	At be- ginning grams	At end, grams	Weight gained, grams	Composi- tion of gain, per cent
Warm empty weight	326,808.0	744,708.0	417,900.0	.....
Water	187,377.6	310,749.9	123,372.3	29.522
Fat	58,918.0	307,163.9	248,245.9	59.403
Nitrogen	9,684.4	15,391.1	5,706.7	1.366
Protein	60,527.5	96,194.4	35,666.9	8.538
Ash	18,612.9	25,696.8	7,083.9	1.695
Phosphorus	3,492.8	4,648.1	1,155.3	0.276

Similarly, by comparison of Steer 48 with Steer 121, the probable composition of the gain of Steer 48 over that of Steer 121 can be calculated. At slaughter Steer 121 had a warm empty weight of 508,513 grams, and a live weight of 569,469 grams. The warm empty weight was 89.30 per cent of the live weight. At the date Steer 121 was slaughtered Steer 48 was off feed, due to his catching cold just after a digestion trial, but he shortly recovered and soon reached the condition of Steer 121, at a live weight of 1280 pounds. Assuming for him the same per cent of fill as Steer 121 the warm

empty weight of Steer 48 would have been 518,472 grams at that time. The calculated composition of the gain of Steer 48 over Steer 121 is shown in Table 64 in which it will be seen that this gain was more than 67 per cent fat and less than 7 per cent protein.

TABLE 64.—CALCULATED COMPOSITION OF GAIN MADE BY STEER 48 OVER STEER 121

	At slaughter of 121, grams	At end, grams	Weight gained, grams	Composi- tion of the gain per cent
Warm empty weight	518,472	744,708	226,236	-----
Water	259,319	310,750	51,431	22.29
Fat	154,089	307,164	153,075	67.66
Nitrogen	13,024	15,391	2,367	1.06
Protein	81,400	96,194	14,794	6.63
Ash	21,475	25,697	4,222	1.87
Phosphorus	3,842	4,648	806	0.36

Still more striking than the composition of the gain was the amount of the gain as compared with the check, Steer 18. A steer is fattened for the increase in amount and quality of the lean flesh. Table 65 gives the calculated gains of carcass and flesh over Steer 18 and also the gains per cent.

TABLE 65.—CALCULATED GAINS OF STEERS 121 AND 48 DURING FATTENING

	Composi- tion of steer 18, kilos	Gain of 121 over 18, kilos	Gain of 48 over 121, kilos	Gain of 48 over 18, kilos	Gain of 121 over 18, per cent	Gain of 48 over 121, per cent	Gain of 48 over 18, per cent
Live animal	342.7	231.1	229.1	437.7	68.1	39.5	117.7
Carcass	202.3	150.5	168.2	306.6	75.8	47.1	140.1
Lean of carcass.....	131.2	69.2	40.6	101.3	53.7	20.1	71.4
Fat of carcass	24.7	68.8	115.9	184.4	283.5	121.7	689.8
Total flesh	159.5	139.0	156.5	286.4	88.7	51.7	166.0
Water in flesh	99.5	51.3	34.1	79.0	52.6	22.4	73.4
Fat in flesh.....	29.8	72.4	111.3	183.1	247.6	107.1	568.5
Protein in flesh.....	29.1	14.0	9.6	21.7	49.2	22.1	69.1

During the fattening period the weight of Steer 121 increased 68.1 per cent, the lean increased 53.7 per cent, and the fat increased 283.5 per cent. During the fattening period the weight of Steer 48 increased 117.7 per cent, the carcass increased 140.1 per cent, the lean flesh 71.4 per cent, and the fat flesh 689.8 per cent. Steer 121 was fattened to a condition that gives choice beef. Steer 48 by increasing this weight 39.5 per cent increased the lean flesh only 20.1 per cent, while the fat flesh (already sufficient) was considerably more than doubled, 121.7 per cent.

The proportion of lean flesh to live weight in Steer 18 was 1 to 2.61; in Steer 121 it was 1 to 2.88; and in Steer 48 it was 1 to 3.33.

Steer 121 required a gain of 3.34 kilos in body weight to make a gain of one kilo of lean flesh over Steer 18. Steer 48 required a gain of 5.64 kilos in body weight to make a gain of one kilo in lean flesh over Steer 121. Similarly a gain of 4.32 kilos in body weight was required by Steer 48 to make a gain of one kilo of lean flesh over Steer 18.

At beef prices which obtained in May, 1918, the carcass of Steer 18 would have sold for \$22.00 a hundred pounds wholesale. If the value of the carcass is assumed to be due to the lean flesh alone the latter should have been worth \$33.92 a hundred pounds to make the carcass worth \$22 a hundred pounds. Valuing the carcasses of the other animals at the same value—\$22.00 a hundred pounds—the lean flesh of Steer 121 should have been worth \$38.80 a hundred pounds and that of Steer 48 should have been worth \$47.53 a hundred pounds. Making similar calculations for the gain only, the lean flesh which Steer 121 gained should have been worth \$47.84 a hundred pounds. The lean flesh which Steer 48 gained over Steer 18 should have been worth \$66.58 a hundred pounds, and the lean flesh which the former gained over Steer 121 should have been worth \$91.14 a hundred pounds.

In Tables 51 to 53 it is seen that Steer 18 had about 54.5 kilos of ether soluble fat in its body, Steer 121 had 151 kilos, and Steer 48 had 307 kilos. The photographs of typical cuts of meat help to visualize these figures. The quantity of fat found in the thin steer would all have been eaten by the average person. The fat in the medium steer would all have been eaten by the lover of good meat. Some persons would have left part of the fat. However, the fat in the highly finished animal was too plentiful for the tastes of normal individuals. The 250 kilos of fat in Steer 48 in excess of that in Steer 18 was expensive to produce, as is shown in Table 30. It cost 3.98 therms per pound above maintenance to produce the gains of Steer 121, but it cost 5.06 therms per pound to produce the gains of Steer 48.

RECOVERY OF PRODUCTIVE ENERGY AND AVAILABILITY OF ENERGY

Food which enters the animal body has a certain amount of total energy, called the heat of combustion. This energy is different in different feeds. Of this total energy the animal loses part by way

of the feces in the undigested food residues, part by way of the urine in incompletely oxidized bodies, and part by way of combustible gases voided. The amount above these losses is called the metabolizable energy. Not all of this matabolizable energy is available for the uses of the animal body in either maintenance or growth. There is a loss due to the work of digestion, mastication, and movement of the food thru the digestive tract. There is also a further loss due to a stimulated metabolism upon the absorption of digestible substances from the alimentary tract. There may be a slightly greater general muscular activity due to the increased food consumed. All this energy is converted into heat and lost from the body. What is left of the matabolizable energy after these second losses are accounted for is called the net, or available, energy. This may be used for production of work, or may be stored in the animal body in the form of protein, fat, or other body substance.

In calculating the thermal equivalent of the fat and protein gained it was necessary to use the data of other investigators. For protein the value of 5.6776 Calories per gram was used. This is the value found by Köhler⁵ for the lean muscular tissue of beef cattle from which the fat had been removed by ether and a correction made for the fat in the residue as determined by the Dornmeyer⁶ method. For fat the value of 9.4889 calories per gram was used. This is the average of four results for beef fat quoted by Fries,⁷ namely those of Stohman and Langbein, Stohman and associates, Gibson, and Danilewsky.

TABLE 66.—ENERGY STORED IN FLESH GAINED

	Steer 121	Steer 48
Fat stored, grams	97,625.5	248,245.9
Thermal equivalent of fat	9.4889	9.4889
Energy in fat, Calories	926,359	2,355,601
Protein stored, grams	24,878.8	35,666.9
Thermal equivalent of protein	5.6776	5.6776
Energy in protein, Calories	141,252	202,502
Total energy stored, Calories	1,067,611	2,558,103

Steer 121 stored 926,359 Calories in the fat gained and 141,252 Calories in the protein gained. This is a total of 1,067,611 Calories. Steer 48 stored 2,355,601 Calories in fat gained, and 202,502 Calories in protein gained. This is a total of 2,558,103 Calories. Table 66. shows the data. The fatter animals' gains cost more to produce but a greater amount of energy was recovered in these gains. Steer

48 gained only 90 per cent more weight than Steer 121 but stored 140 per cent more energy. In order to make these gains and store this energy these animals consumed a large amount of feed. Steer 121 consumed more than two thousand pounds of digestible organic nutrients and Steer 48 consumed nearly eight thousand pounds.

The metabolizable energy that may be used for production of flesh is that amount above the needs for maintenance. By using the average weight of the animal while on maintenance and the maintenance cost found by trial for each, the cost of maintenance during the full feed period was calculated. The amounts of energy required for maintenance at different body weights were found to be proportional to the body surfaces, that is, roughly to the two-thirds power of the body weights. It has been shown in previously published work³ that the surface area of a thin or medium fleshed steer is more nearly proportional to the five-eighths power of the weight, while that of the very fat steer is proportional to the five-ninths power. The five-ninths power was used in the calculations for the animals in this investigation.

TABLE 67.—AVAILABLE ENERGY

	Steer 121	Steer 48
Length of period, days	153	567
Weight gained, pounds	502.2	963.5
Average weight of animal, pounds	1,041.1	1,384.3
Energy per 1000 lbs. for maintenance, therms.....	12.14	12.73
Metabolizable energy, therms	3,899.59	13,518.57
Total energy for maintenance, therms	1,899.80	8,645.47
Energy above maintenance, therms	1,999.79	4,873.10
Energy above maintenance per pound of gain, therms.....	3.98	5.06
Energy recovered in gain, therms	1,067.61	2,558.10
Per cent metabolizable energy recovered	53.39	52.49

According to the theory in the foregoing paragraph the cost of maintenance for the thin animals, Steer 121 and Steer 48, should have been proportional to the five-eighths power of the weights until they could be classed as fat, and after that the proportion should have been changed to the five-ninths power. A calculation was made by using the five-eighths power entirely. This made a difference of 0.25 per cent of the net energy cost of a pound of gain for Steer 18, and 1.5 per cent for Steer 48 thruout the entire period. The true value would lie between the one given in Table 67 and a value smaller by the amount just shown. Therefore the error could hardly have been

more than one-half that shown, or about 0.75 per cent of the total amount for Steer 48. The error in the calculation of the per cent of available energy would have been about double this error. The small size of the error involved made it inadvisable to use a more complex method of calculation than that employed.

The results of the calculations given in Table 67 show a much higher productive energy cost of each pound of gain for the very fat steer than for the medium fat steer. Tables 62 and 63 show that the gains of Steer 48 were about 29 per cent more fat than those of Steer 121. The productive energy consumed increased in about the same proportion (27 per cent) from 3.98 therms per pound to 5.06 therms.

In the tissue gained by these animals one recovered 53.39 per cent of the metabolizable energy consumed above maintenance and the other recovered 52.49 per cent. Thus it is seen that the very fat steer saved almost as much of the energy above maintenance as the medium fat steer. These figures average 52.94 per cent. Since this proportion of the energy was recovered it may be said that this was a measure of the availability and that the metabolizable energy of the ration here used was 52.94 per cent available, or net.

TABLE 68.—AVAILABLE ENERGY CALCULATED FROM WORK OF ARMSBY
(Therms per kilogram dry matter eaten)

Animal	Experiment	Total energy therms	Metabolizable energy therms	Heat increment therms	Net energy therms	Available per cent
E	208	4532.67	2624.67	1166	1458.67	55.58
C	208	4539.50	2516.50	1139	1377.50	54.75
F	209	4519.33	2625.33	1105	1520.33	57.90
Average .....	.....	4530.50	2588.83	1136.67	1452.17	56.09

In the work of Armsby, previously referred to, animals were used similar to those discussed herein and a ration somewhat similar—alfalfa hay and grain mixture No. 2—was used. The availability has been calculated from the data given.⁸ Table 68 shows the results. It is seen that an average of 56.09 per cent of the metabolizable energy was available. Since the ration used by Armsby was richer in grain than the one used at the Missouri Agricultural Experiment Station, it is advisable to calculate the availability from figures given elsewhere by Armsby. He shows⁹ that alfalfa hay contains 44 per cent of metabolizable and 17 per cent of net energy. This makes the net 38.636 per cent of the matabolizable. For grain mix-

ture No. 2 he shows 65 per cent of metabolizable energy and 40 per cent of net energy. This makes the net energy 61.538 per cent of the metabolizable. By putting these two together in the ratio of five parts of grain to two parts of hay (the Missouri ration) the value of 54.995 per cent available energy is obtained. Armsby's figures show the ration to be 55 per cent available, while the energy stored by the steers used in the work discussed herein shows the ration to be about 53 per cent available. This is a remarkably close agreement and is an experimental verification of the work done by Armsby in his calorimeter. These results have been published in brief form elsewhere.¹⁰

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**SOME FACTORS INFLUENCING THE
RATE OF GROWTH AND THE SIZE
OF DAIRY HEIFERS AT MATURITY**



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SOME FACTORS INFLUENCING THE RATE OF GROWTH AND THE SIZE OF DAIRY HEIFERS AT MATURITY

C. H. ECKLES AND W. W. SWETT

Probably in no field of investigation connected with agriculture has work in recent years been of greater significance than that concerning the factors connected with the growth of domestic animals. The amount of attention given to this subject is not at all surprising when the limited extent of scientific knowledge of the subject and the tremendous economic importance of the questions involved are considered.

In the dairy herds of the United States alone not less than eight million heifers are on hand at any one time. No less than four million must come to maturity each year to replace dairy cows already in use. The annual cost of raising these heifers is approximately \$250,000,000. The grower of dairy cattle is confronted not only with the large expense of raising these animals and of supplying proper rations but with questions as to the possible effect of various factors involved upon the growth and future usefulness of the animals. Examples of these questions are: the influence of gestation and lactation upon the rate of growth; relation of the size of the calf at birth to future development; influence of the age at first freshening upon the size of the cow when mature; the relation of liberality of the ration to rate of growth and size of animal at maturity. The careful observers of dairy cattle in practical herds ask many questions concerning growth, such as what is the cause of the marked variations in the average size of dairy animals of the same breed in different herds and between individuals within a herd.

A consideration of the more practical side of these and certain other questions based upon extensive investigations concerning the growth and development of dairy heifers is found in an earlier publication by the Missouri Experiment Station.¹ The object of this bulletin is to present in a more complete form and with less attention to the practical side of the question involved certain data concerning the factors which influence growth.

Nature of growth.—Mendel² says there is no satisfactory definition of "growth". The word, however, is usually understood as indicative of that series of physiological changes by which an individual of any species develops from the fertilized egg to maturity. When the parent cells unite at the time fertilization of the egg takes place, in some manner a force is set free which has been termed by some the "growing impulse", by others the "growth tendency" or "inherent tendency to grow".

According to Minot,³ the impulse to grow is imparted with the union of the generative cells, and uterine life is characterized by rapid growth. He estimates that in the early embryonic stages rabbits grow as much as 1000 per cent in a day, and that over 98 per cent of the growth impulse is lost before birth. An animal, then, begins ex-uterine life with less than two per cent of the original growth power with which it was endowed.

It seems to be the general opinion that hormones or secretions of ductless glands are responsible for the growth stimulation. Killicott⁴ says, "It seems likely that in organisms in general the normal growth of each tissue or of each organ is controlled separately by a specific internal secretion. These substances may regulate growth either thru inhibition or acceleration, and the effect produced may be due either to the presence or the withdrawal of the specific substance." The glands supposed to be especially connected with the phenomena of growth are the thyroid, the pituitary body, the pineal body, and the thymus.

The individual has an inheritance or growth impulse which makes it possible to attain a certain size, and even the greatest intake of food will not cause this limit to be exceeded. Nutrition, which is often looked upon as a controlling factor, can do no more than give free scope to the inherent tendency to grow which the animal has received at birth.

The tendency of the animal body is to grow at a regular but constantly decreasing rate of speed from birth to maturity. In spite of this general tendency which manifests itself under uniform and good conditions, growth is influenced to a considerable extent by the conditions under which the animal is forced to live. The "growth tendency" evidently exists to a greater extent within the skeleton than within the tissues. The body weight of the animal may be influenced very decidedly by a change in conditions, but the upper limit of the skeletal size of an animal is determined by heredity. The stature which an animal may attain within the

definite limits fixed by heredity is directly related to the treatment received during its period of growth. Morgan⁵ believes it is due to an inhibitory factor developed within the body. Insufficiency of food will result in checking or stopping growth, but this is an abnormal condition.

Investigations concerning growth.—Experiments concerning growth have been conducted generally with small laboratory animals. The work of Osborne and Mendel is based almost entirely upon results with white rats. Hart and McCollum have generally used white rats but report some investigations with swine, fowls and cattle. Aron experimented with dogs, and Waters with cattle and swine. Considerable work, largely of a statistical nature, has also been done with human beings. While the fundamental facts concerning growth as established by the use of laboratory animals are generally assumed to apply to other species, including domestic animals, there is still some uncertainty of the extent to which this is the case. Waters was among the first to report extensive investigations with cattle.

It has been assumed by a few writers that an animal must grow at a maximum rate practically every day from birth to maturity to reach the full stature as fixed by heredity. According to Waters⁶ this is only to assume, "that the organism is utterly incapable of compensating for any retarded development at any time in its growth period, either by a subsequently increased rate of growth, or by extending, even the slightest degree, the growth cycle, much less by growing at a time when so sparsely fed that no gain in weight occurs."

It was noted by Waters that the tendency to recover was strong following a period of adverse conditions. After a severe illness of short duration the animal usually increases its rate of growth and compensates for the check in growth. As a rule, the longer the period of adversity the less complete will be the recovery. Whether or not the compensation is ever entirely complete is questionable.

In an experiment carried on by Waters,⁷ 15 growing beef animals of different ages were kept for one year on a ration of maintenance, or one which maintained a constant weight without permitting gains. Under such conditions extensive growth of skeleton took place in every case. Aron⁸ experimenting with dogs secured similar results. Waters⁹ found that an animal which received even less than a maintenance ration made skeleton growth for about six months, after which the growth continued for a time, but varied directly in proportion to the ration given. In these ex-

periments it was noted that the animals on a low nutritive plane developed a form characterized by being abnormally narrow in certain parts. Poor nutrition exerted a more pronounced effect upon the width than upon the height of the animal.

Until recently the nutritional requirements for growth were assumed to be met by a ration which supplied sufficient calories together with a certain amount of protein. As a result there are several feeding standards such as Armsby's, the Wolf-Lehman, and others which undertake to set forth the nutritional requirements. Armsby expresses the requirements in "digestible true protein" and "net energy", while the Wolf-Lehman standard uses "digestible crude protein" and "digestible carbohydrates" and "ether extract."

The mineral demands of the growing body were recognized, but little was known concerning the requirements. It was generally assumed that there was little danger of a shortage in mineral constituents.

As a result of important investigations in recent years, especially those by Mendel and Osborne, and McCollum and Hart, the problem of nutrition is now known to be far more complex.

These investigations have made it clear that the nutritional requirements cannot be expressed in terms of digestible nutrients alone. According to McCollum¹⁰, in addition to sufficient energy, four other factors must be taken into account: (1) Quantity and quality of proteins; (2) character of the inorganic constituents; (3) presence of unidentified dietary factors, fat soluble A and water soluble B. Nutritive disaster follows if any of these are absent or of an inadequate character. A consideration of these factors in relation to growth of dairy animals does not come within the scope of this paper, except as the question may be raised regarding the possibility of the results reported on the experimental animals used having been influenced by the inadequacy of the ration with reference to some of these nutritional factors.

SOURCE OF DATA

The data upon which this paper is based have been taken on animals in the dairy herd of the University of Missouri. A small portion of the data is from general records kept of the herd. For example, records of the weights of calves at birth and the weights of the dams following parturition have been kept for twelve years. Another portion of the data is obtained from records covering a series of years which have been taken by this Experiment Station

for the purpose of determining a normal growth curve of dairy heifers. The animals which supplied this data have been kept under what is considered normal conditions. Up to six months of age the animals received a ration based chiefly upon milk. Whole milk was given for the first two weeks followed by skim milk for the remainder of the period. From the time the heifers were two weeks old, up to first parturition they received, during the winter season, a ration composed of alfalfa hay and corn silage with a small grain allowance in most cases. During the pasturing season the animals were kept on a good blue grass pasture. The object was to maintain the animals in a good thrifty condition but not to allow them to become fat.

The greater part of the material used, however, is based upon data covering eight years which were accumulated during an investigation by this Experiment Station, the objects of which were: (1) To determine the effect of the liberality of the ration during the growing period and; (2) the influence of the age at first calving upon the growth, size at maturity, and milking characteristics of dairy heifers. Forty-two purebred heifers of the Jersey, Holstein, and Ayrshire breeds were used. One-half of these received from birth to time of first parturition what is referred to later as the "heavy ration." This group received whole milk from birth to the time they were six months old. A grain ration consisting of corn and oats, and alfalfa hay was fed practically ad libitum during the winter months, while in summer a portion of the group was on pasture and received in addition a liberal grain allowance.

The second group, referred to later as the "light-fed group", received whole milk for two weeks then skim milk until they were six months old. Alfalfa hay was fed ad libitum during the winter, and in the summer a part of the group was on pasture. This group was not limited in the amount of food offered; but since it was limited to roughage, the amount of digestible nutrients consumed was far less than that taken by the group which received the ration containing large amounts of concentrates. While the experiment was planned primarily to compare a heavy and a light ration, it was later decided that it was rather a comparison between a very liberal and a moderate ration, since many dairy animals under practical conditions receive a ration inferior to that which was received by the light-fed group.

The factor of age at first calving was introduced by having one-half of both the heavy and light-fed groups calve at what would be

an early age for the breed, and the remainder at what would be a late age. The Jerseys averaged 22.7 months for the early and 34.9 months for the late-calving group. The averages for the Holsteins were 23 months for the early, and 34.3 months for the late-calving group. After parturition all were placed on the same ration which consisted of an abundance of silage and hay, with an allowance of a grain mixture of 4 parts corn, 2 parts bran, 1 part oil meal. The grain mixture was fed in proportion to the amount of milk produced.

It is believed all requirements for an adequate ration as laid down by McCollum were met in these rations. The alfalfa hay supplied an abundance of calcium and of the growth accessory, fat soluble A, also plenty of protein known to be efficient when fed with grain. The corn supplied ample phosphorus, and together with the oats a liberal amount of the water soluble B. The animals which received the alfalfa alone showed every evidence of being well nourished and were in the best of health. It was noticeable that the group which received the liberal ration appeared decidedly older and better developed than the light-fed group at the same age.

Weights and Measurements.—In the investigation concerning factors which influence the growth of dairy heifers, reference to which has been made, the animals were weighed monthly. In the first part of the experiment they were weighed on the day nearest the middle of the calendar month. Later, as a result of the extreme variations in weights which appeared from month to month in data taken in this manner, the plan was changed to include weighings on three successive days at the middle of the month; and the average of these weights was used as the correct figure. This plan was continued until the animals were dropped from the experiment, at which time they were from six to eight years old. The same plan has been followed in taking the weights for determining the normal growth, except that as a result of experience the plan was modified to include monthly weights up to parturition. After parturition, weights for three days were taken and again six months after parturition. A series of monthly weights were thus obtained up to the first parturition and following this another series was taken under reasonably uniform conditions. The 42 animals used in the experiment in which the liberal ration was compared with the light were measured monthly from the time they were one month old until cessation of growth occurred.

The following is a list of the measurements taken:

1. Height at withers
2. Height at a point between the hips

3. Height at hip points
4. Depth of chest just behind "elbow" joint
5. Width of chest just behind "elbow" joint
6. Width of hips (hip points)
7. Width of loin (center)
8. Length from poll to point of muzzle
9. Width of forehead
10. Circumference of muzzle at opening of mouth
11. Length from base of horns to withers
12. From highest point of withers to a line between hips
13. From a line between hips to tail
14. From point of shoulder to point of hips
15. From point of shoulder to ischium
16. From point of hip to ischium
17. From point of hips directly forward to last rib
(To point at angle between loin and rib)
18. Heart girth just behind elbow joint
19. Girth of paunch at end of last rib
20. Smallest circumference of shin bone of foreleg
21. Smallest circumference of shin bone of hind leg

As a result of some study given this enormous accumulation of data, it was decided that only a few of the measurements taken are of any special significance. It was further decided that the growth of the animal, as far as the skeleton is concerned, can be determined reasonably well by a few measurements, and sufficiently well for most purposes, by one measurement alone. The one selected was height at withers.

As a result of this decision in our more recent studies of growth the skeletal measurements have been limited to that of height at withers. In taking this measurement it was observed by Regan¹¹ that fluctuations occurred which were too large to be considered as errors. At times an animal would measure two or three centimeters lower than the previous month. Regan found that the chief cause for this fluctuation was that the animal being measured, when allowed to stand for a short interval, gradually decreased in height. The backbone was observed to sink from a position above the shoulder blades until it was often below the level of the top of the shoulder blade. This is apparently the result of relaxation and stretching of the muscles. So long as the animal is in motion these muscles are tense and hold the body at a higher point, but as soon as the animal is quiet these muscles relax and the body settles appre-

ciably. The animal upon moving again assumes its full height. To avoid this error the plan of measuring each animal three times in succession was adopted, and the animal was moved about between the times of taking the readings. The readings were also made as quickly as possible after the animal came to a rest.

THE METHOD OF MEASURING GROWTH

Until comparatively recent times the growth of animals has been measured almost entirely by means of their body weight. It is now recognized that this is not a satisfactory way to measure growth, because body weight and skeletal growth are, to a considerable degree, independent of each other. Apparently the "growth tendency" applies much stronger to the skeleton than to the tissues of the body. As already stated, Waters found it possible for an animal to grow in height and remain at constant weight for extended periods of time, or in extreme cases, even to make skeletal growth while losing in weight. The animal body seems to act as a storehouse. The growth of the skeleton continues to a certain extent, whether the tissues are storing up energy during a period of liberal feeding, or whether they are giving up energy as the result of a low plane of nutrition. An illustration of the greater effect of feed on weight than on skeletal growth is shown in Tables 1 and 2. These tables show a comparison for groups of animals of the effect of the ration upon growth of skeleton, and upon increase in body weight. The values given represent the weight and height in percentage of the normal for animals of the same age.

TABLE 1.—WEIGHT IN POUNDS IN PERCENTAGE OF THE NORMAL

Age months	Jerseys		Holsteins	
	Light-fed	Heavy-fed	Light-fed	Heavy-fed
6	95	99	85	120
12	80	104	73	118
18	83	128	84	130
24	84	109	88	119

TABLE 2.—HEIGHT AT WITHERS IN PERCENTAGE OF THE NORMAL

Age months	Jerseys		Holsteins	
	Light-fed	Heavy-fed	Light-fed	Heavy fed
6	98	99	96	102
12	95	101	93	103
18	95	102	95	103
24	96	101	97	103

It will be noted in examining the foregoing tables that the greatest difference in percentages of gains in weight occurred with Jerseys between 12 and 18 months old. At this time it amounted to 45 per cent. The greatest corresponding difference in percentage increase in height at withers occurred at the same age and amounted to only 7 per cent. An examination of figures for Holsteins shows similar results. The greatest difference in weight percentages was 46, while the difference in height at withers for the same period was only 8. The greatest difference in this entire group of Holsteins occurred with animals between 6 and 12 months old when it amounted to 10 per cent.

The weight of an animal certainly cannot be used alone as a fair measure of growth when the weight in relation to the growth of the skeleton can so readily be made to fluctuate between such wide limits. Attempts have been made to find a way to represent growth by a single term but as yet no satisfactory method has been devised. It seems necessary to represent the growth of body tissue in one term, and that of the skeleton by another. So far, no more satisfactory method than weight has been suggested for measuring increase in body tissue, and the skeletal growth by means of certain measurements.

If it is assumed that skeletal measurements in addition to weights, are essential in measuring growth, then the question at once arises which of the many possible measurements shall be used. Can any one measurement be used as an index to the growth of an animal? In several recent investigations the height at withers has been used to represent the skeletal growth. Is it satisfactory to base conclusions on any one measurement? With the idea in mind of answering these questions, a portion of the large amount of data on measurements were selected in such a way that the different dimensions of the body were represented, and these were studied to see if any correlation could be found.

In considering the skeletal growth of an animal the height first attracts attention. Among the different measurements taken on the experimental animals were two of height, one at the highest point of the withers (A) and the other at the hip-points (G). (Fig. 1).

The circumference of the body seemed best represented by the measurement taken at the heart girth (E-F), while the width between hip-points was chosen to represent the width development of the posterior part of the body. The third dimension, length, might be represented by a number of different measurements but the

one chosen for this purpose was that which represented the distance from the point of shoulder to the point of ischium (C-D).

When these five measurements which seem to represent fairly well the dimensions of the body were decided upon, the next problem was to select the animals to be used as a source of the data. Since the measurements were complete from birth for only a part of the heifers, it seemed best to limit the preliminary study to sixteen representative animals four of which were included in each of the following groups:—

- (a) Heavy-fed Jerseys (c) Heavy-fed Holsteins
- (b) Light-fed Jerseys (d) Light-fed Holsteins

Since the study was of a preliminary nature only, the values were not plotted for every month but only for the first, second, third, sixth, ninth, twelfth, eighteenth, twenty-fourth, thirtieth, thirty-sixth, forty-eight, and sixtieth months. The relatively rapid growth at an early age was the reason for the short intervals between the plottings at the beginning.

Three or more methods may be used to represent growth in a tabular or graphical form. The first method is to plot the values of the measurements taken directly in centimeters. A curve plotted by this plan shows the size of the animal at any age and indicates at which points growth takes place. Such a method is satisfactory in comparing the relative increases of corresponding measurements of animals under different conditions. This method, however, cannot be used in comparing the relative increases of the different parts of the body, because it would involve comparing measurements of small value, such as increase in width at hips, with those of large value, such as the increase in heart-girth or the length of the animal. The only satisfactory way to compare the relative growth of the body parts seems to be by some percentage basis.

The second method is to calculate the amount of the increase at each point over the original measurement. By this method, if the animal or group of animals, was found to measure 70 centimeters as an average, at the beginning of the experiment and 84 centimeters at the next calculation, the increase would be 14 centimeters which amounts to 20 per cent. If the next measurement should be 91 centimeters the increase over 70 centimeters would be 21 centimeters or 30 per cent. In each case the percentage increase is based upon the original or beginning measurement. The method shows in a tabular or graphical form the amount of growth in terms of percent-

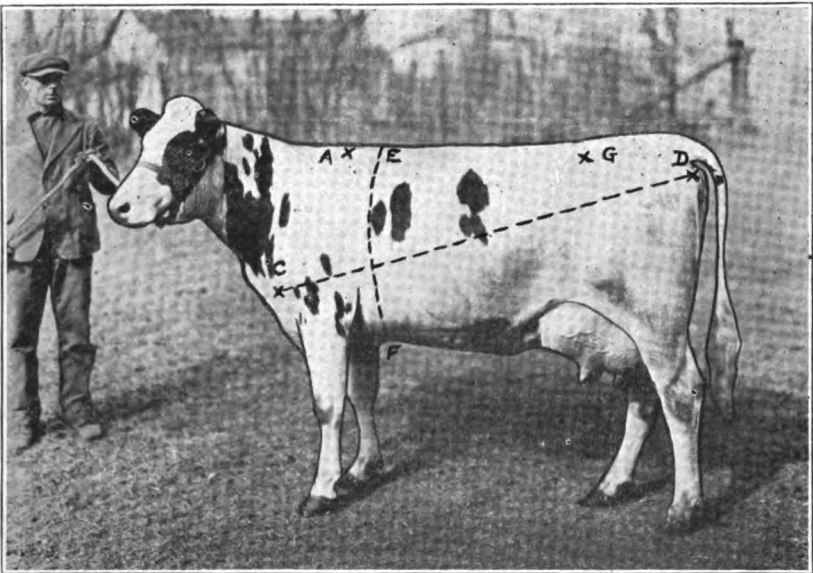


FIG. 1.—The points of anatomy used in making measurements to determine skeletal growth: A, Withers; C, point of shoulder; D, ischium; E - F, heart girth; G, hip points

ages of the first measurement. This method of representing growth is illustrated in Fig. 2.

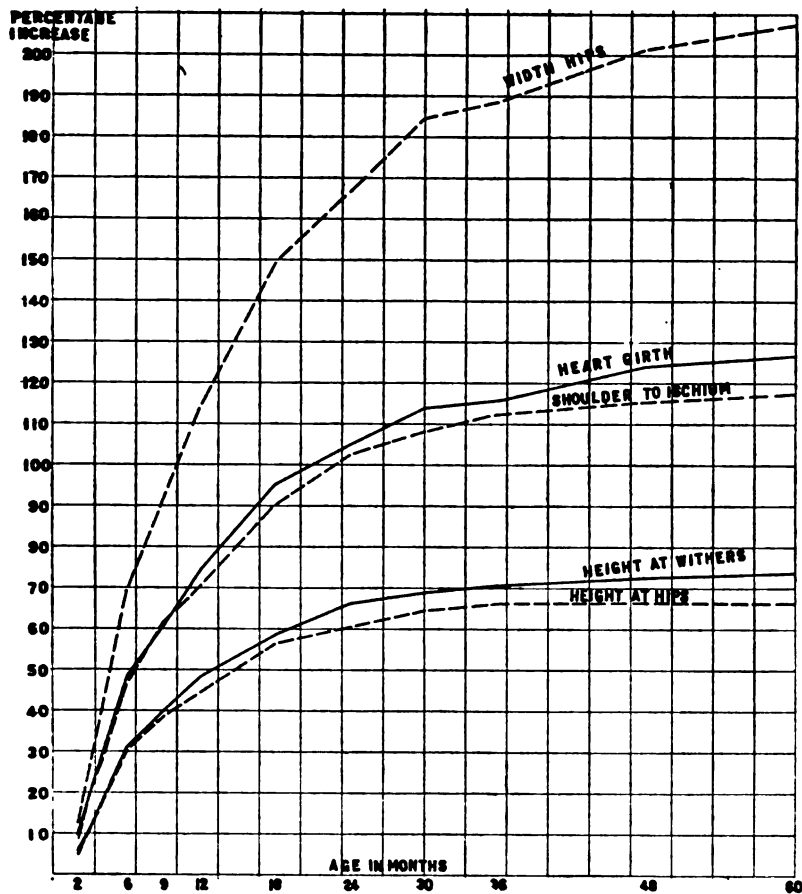


FIG. 2.—Growth of the body as represented by five different measurements and expressed in percentages. The figure is based upon the percentage increase of the measurements used over the first measurement taken at the age of one month. The height of the animal never doubles from one month of age to maturity, while the heart girth and length more than double and the width of hips more than triples during the same period. (Table 3)

The third plan is to consider the rate rather than the amount of growth by calculating the increase made in each period over the preceding value, and expressing the result in per cent. As an example of the method, the first value may be assumed to be 70 centimeters and the second 84 centimeters. In this case the increase is 14 centimeters or 20 per cent, as by the first method. But now suppose

the next value is 91 centimeters. Here the gain for the period is only 7 centimeters and expressed in terms of per cent is only 8.3 per cent of 84. This gives a downward instead of an upward curve. By this method each increase is taken as a unit, and the percentage is based upon the preceding measurement. The rate is wholly dependent upon the size of the animal at the time and diminishes rapidly as the size of the animal increases. The second and third methods of representing growth are illustrated in Fig. 3.

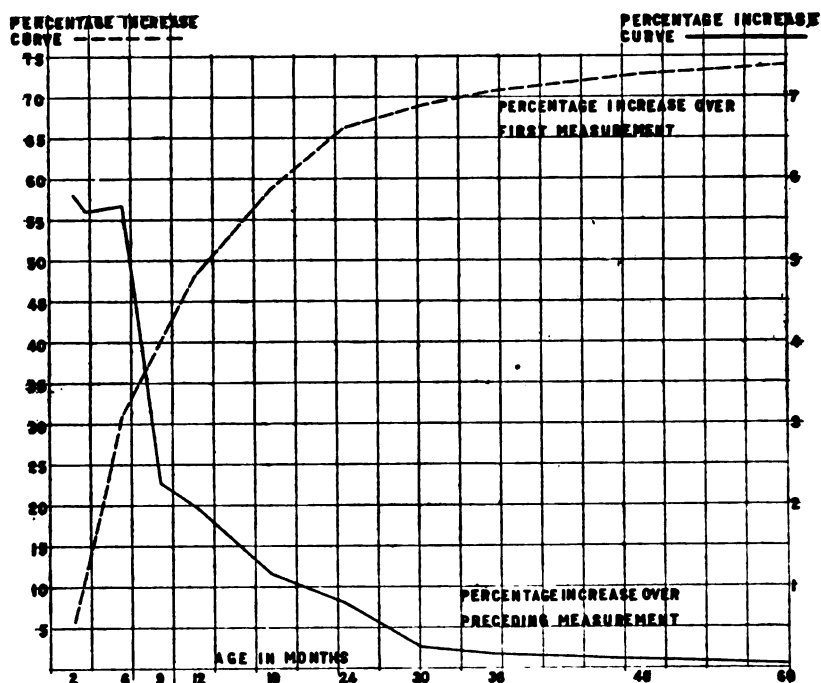


FIG. 3.—Two ways of representing growth. This figure is based upon measurements of height at withers. The solid line represents the percentage increase during each period over the preceding measurement. The broken line represents the percentage increase during each period over the measurement taken at the age of one month. The maximum percentage increase by the first method is 5.8. In the second method it is 73.9. The data from these two methods when plotted appear in the form of reversed curves

These two methods at first seem contradictory because when expressed graphically they give reversed curves. A more careful consideration, however, shows that they are consistent.

The method which represents the amount of growth is based on the average measurements of the 16 animals when one month old.

The point which represents maturity was set at 60 months. The amounts of increase of body parts in terms of per cent from the time the heifers were one month old to maturity was found to be as follows:

Height at withers	73.9 per cent
Height at hip-points	66.3 per cent
Length (shoulder to ischium).....	117.3 per cent
Heart girth	126.9 per cent
Width at hip-points	207.2 per cent

These values are shown in Table 3 and Fig. 2.

TABLE 3.—AMOUNT INCREASE OVER FIRST MEASUREMENT IN PER CENT

Age months	Height at withers	Height at hips	Point of shoulder to ischium	Heart girth	Width of hips
1	...	...	....	....	....
2	5.8	5.0	8.8	9.6	12.5
3	11.8	11.8	20.0	20.1	28.0
6	31.0	30.4	46.4	48.8	69.6
9	40.0	38.6	61.9	61.0	92.9
12	48.3	44.5	70.8	74.9	114.3
18	58.6	56.4	90.1	95.1	149.4
24	66.2	60.5	102.7	104.9	166.6
30	68.9	64.3	108.0	113.7	184.5
36	70.7	66.1	112.5	115.7	188.7
48	72.8	66.5	115.4	124.0	201.2
60	73.9	66.3	117.3	126.9	207.2

The most striking thing about these figures is that the animal never doubles its height. It seems almost impossible that a calf one month old is considerably more than half as tall as the mature cow. This fact is especially striking when the cow and calf are seen together. Check measurements, however, bear out the figures derived in the preliminary study.

The first impression from a glance at these figures is that one measurement cannot be used to represent the general body growth and that surely, when an animal never doubles its height, when it more than doubles its circumference, and when it more than triples its width, the growth of the different parts of the body is all out of proportion. A more complete study of the situation, however, shows that while one part of the body may double and another part, triple

itself, the relation of the growth of one part to another is very nearly constant at all ages.

TABLE 4.—RELATIVE AMOUNTS OF PERCENTAGE INCREASE OF DIFFERENT BODY PARTS

Age months	Height at withers	Height at hips	Length shoulder to ischium	Heart girth	Width of hips
2	1.000	.862	1.517	1.655	2.155
6	1.000	.980	1.496	1.574	2.245
12	1.000	.921	1.466	1.551	2.366
24	1.000	.915	1.554	1.587	2.521
36	1.000	.935	1.591	1.636	2.668
48	1.000	.913	1.584	1.703	2.762
60	1.000	.897	1.587	1.717	2.803
Average	1.000	.917	1.542	1.632	2.503

This fact may be seen in Table 4 which was derived by dividing the percentages of increase for the different measurements by the value for the height at withers. The increase in height at withers is used as the basis of comparison and is given a value of 1. All other measurements are compared to it in the form of a ratio. For each 1 per cent increase in height at withers up to two months the height at hips shows a gain of .862 per cent and the length of the body 1.517 per cent. The uniformity of the relation between the different measurements at all ages indicates that the increase of the different body parts expressed in percentage continues in much the same proportion thruout the growing period. It will be noticed that there is a tendency for the values for the heart girth and width of hips to increase with age. This increase in value for heart girth can be easily explained by the observed fact that flesh deposition continues to a large extent after the growth of the skeleton ceases. Flesh deposition takes place presumably at all points around the circumference of the animal which results in a considerable increase in this measurement. It is a commonly observed fact that the hips seem to broaden rather rapidly in the more mature animal; so the ratio for the increase in the width of hips tends to widen. The reason for the relatively greater increase in width of hips over other parts of the body has never been satisfactorily explained. Taking all the data into account it is safe to say that the growth of the various parts of the body proceeds in rather definite ratios. The

rapid increase in length comes at the same time as the rapid gain in height or circumference; so a measurement taken of the growth of one part of the body makes it possible to estimate closely the rapidity of growth and the time at which it occurs. The general conclusion seems justified from these considerations that any one of the fundamental measurements of the body may be used with a fair degree of accuracy as an index of skeletal growth.

Since the error in taking measurements which represent the height at withers seems to be as slight as any and to be affected to as small extent as any by varying conditions of the animal, this measurement has been chosen as a standard to represent skeletal development.

WEIGHT OF CALF AT BIRTH

The question is often raised as to the relation of the size of the calf at birth to the rate of growth and the size of the animal at maturity. The practical importance of this question is evident. An attempt was made to answer this question from a study of the data available from the University of Missouri dairy herd.

Table 5 shows data taken on heifers used in the experiment to determine the normal rate of growth for dairy animals. These heifers received what is considered a normal ration for an animal of the age and breed from birth to maturity. Both the Jerseys and Holsteins are divided into three groups, the first group includes those noticeably below the average in weight at birth, the second group those about normal, and the third group those above normal. While the number of animals supplying the data is unfortunately not as large as would be desirable, still if the factor involved is important enough to deserve much attention the results should be apparent. It happened with both breeds that the groups which were above and below normal at birth averaged higher at withers when 24 months old than the group which was of medium size at birth. The normal height at withers of a Holstein 24 months old is 126.5 centimeters and of a Jersey 120.4 centimeters. The data show that all five of the Holsteins below normal in weight at birth were normal or above at 24 months. Of the four approximately normal in weight at birth, all were below normal at 24 months; and of the six above normal at birth, four were above and two below normal at the same age.

Of the five Jerseys in the group below average at birth, only one was above normal at 24 months; of the four near normal weight

TABLE 5.—RELATION OF BIRTH WEIGHTS TO RATE OF GROWTH—ANIMALS ON NORMAL RATIONS

Cow No.	Weight at birth	Height at withers 6 mo.	Height at withers 12 mo.	Height at withers 18 mo.	Height at withers 24 mo.
	lbs.	cm.	cm.	cm.	cm.
Holstein Normal	89	100.9	114.0	121.8	126.5
235	75	....	....	....	126.5
238	81	....	112.0	121.5	128.0
243	85	104.7	112.6	123.3	128.0
239	85	....	114.0	123.0	131.5
Average	81	104.7	112.9	122.6	128.5
237	87	....	....	....	126.0
244	87	97.0	112.0	120.3	125.0
236	90	96.7	....	....	123.0
249	90	96.9	111.3	118.0	126.3
Average	89	96.9	111.7	119.2	125.1
241	92	102.0	115.5	120.5	126.8
245	95	101.0	111.5	119.3	123.5
248	97	99.3	113.5	119.8	126.0
246	102	102.0	114.8	123.5	128.1
251	110	104.2	119.3	124.5	133.0
Average	99	101.7	114.9	121.5	127.3
Jersey Normal	54	93.7	108.3	115.6	120.4
91	35	....	105.0	113.3	119.8
96	40	96.0	111.2	120.3	123.5
61	50	....	108.1	....	119.5
102	50	89.5	103.5	110.0	114.1
90	50	....	109.5	115.3	120.0
Average	45	92.7	107.3	114.7	119.3
98	55	97.0	110.5	117.7	120.0
100	55	90.7	107.0	113.8	119.3
101	57	94.0	109.5	115.8	118.4
Average	56	93.9	109.0	115.7	119.2
93	63	....	110.0	115.0	123.3
95	65	95.0	110.5	117.5	124.5
89	70	....	106.5	115.0	120.0
87	72	....	....	118.0	121.7
Average	68	95.0	109.0	116.6	122.3

at birth, all were below normal at 24 months; and in the group of four above normal at birth, three were above and one below normal at 24 months. These data possibly show a very slight tendency toward the animals larger at birth maintaining a lead over the normal during the period of most rapid growth, but individual variations are marked.

TABLE 6.—RELATION OF BIRTH WEIGHT TO MATURE HEIGHT AT WITHERS

Herd No. Cow	Birth weight	Height withers mature	Herd No. Cow	Birth weight	Height withers mature
	lbs.	cm.		lbs.	cm.
Normal	89	135.8		54	125.6
217	55	133.2	41	32	125.0
228	60	130.3	2	35	125.0
224	70	130.0	54	40	126.3
219	75	127.1	55	40	124.9
214	75	134.8	57	42	121.1
211	75	135.5	59	45	125.4
235	75	137.5			
Average	69	132.6	Average	39	124.6
231	90	132.0	39	50	120.0
227	80	132.9	13	50	123.4
221	85	140.9	22	30	119.7
237	87	134.9	50	52	128.1
222	90	130.6	58	55	125.0
223	90	134.4	8	55	124.3
213	94	134.0	14	55	119.0
			64	56	131.0
Average	88	134.2	Average	52.9	123.8
210	100	139.0	56	60	126.5
226	100	130.3	53	60	135.8
216	102	135.3	23	62	126.1
208	105	142.2	11	67	122.1
215	112	137.5	17	67	125.3
Average	103.8	136.8	Average	63.2	127.1

Table 6 gives the birth weight and height at withers at maturity for groups of Holsteins and Jerseys taken from data available for the University of Missouri herd, and which are not included in that data which represents the normal growth determination. The first group includes the animals smallest at birth of those which supply

our data. No animal known to have been born prematurely is included. It will be noted in this table that there appears to be more relation between size at birth and size at maturity, and with the Holsteins the groups at maturity rank in size in the same order as at birth. In the case of the Jerseys, those largest at birth were also the largest at maturity, but those smallest at maturity were on the average with the group medium sized at birth.

TABLE 7.—A STUDY OF INDIVIDUAL BIRTH WEIGHTS

Age	Cow	Weight	Height	Cow	Weight	Height
months		lbs.	cm.		lbs.	cm.
Birth	2	35	....	17	67	....
1		72	71.1		87	75.0
2		98	75.0		117	80.8
3		130	79.7		151	85.5
6		288	95.1		282	98.0
12		572	112.5		472	112.5
18		852	119.8		705	118.3
27		748	123.8		637	122.0
33		707	124.8		792	124.2
46		935	125.0		815	125.8
60		...	125.0		....	125.5
Birth	41	32	....	53	60	....
19		747	119.0		785	121.6
20		...	119.0		....	125.0
28		962	122.5		1055	132.0
34		1031	123.5		1110	135.0
48		870	125.8		1122	135.3
54		851	125.3		1185	135.5
60		...	124.0		....	134.8
Birth	48	55	....	59	55	....
19		538	111.5		463	113.0
24		505	113.0		620	119.0
30		575	115.5		657	122.0
42		657	118.0		740	124.8
50		690	119.8		849	126.5
56		724	....		....	....
60		...	119.3		....	125.5

Table 7 gives records in detail for six animals selected to illustrate that, in individual cases at least, there is no definite relation between the birth weight and the final size. Cows 2 and 41 were

only 65 per cent of normal size at birth but at maturity were practically normal sized animals and were decidedly larger than Cow 48 which weighed 105 per cent of normal at birth. Cow 17 was 126 per cent of normal at birth but was the same size at maturity as Cow 2 which was only 65 per cent normal at birth. Cow 53 was 115 per cent normal at birth and at maturity was 106 per cent of normal height. Cow 59 was practically normal in birth weight, also in height at maturity. Cow 2 weighing 35 pounds at birth was practically the same size when mature as Cow 67 which weighed nearly twice as much at birth. On the other hand, Cow 41 weighing 32 pounds at birth, altho she attained nearly normal size when mature, was far behind Cow 53 which had a weight nearly twice as great at birth. Cows 48 and 59 starting at the same birth weight showed a marked difference in size at maturity.

The data in Table 7 indicate that the size at birth does not necessarily, in individual cases, bear any relation to the rate of growth or size at maturity.

When the data as a whole are considered, there is little evidence of a relationship between the size of animals at birth and at maturity. The most that can be said is that generally there seems to be a slight tendency in that direction, but individuals show such wide variations that little practical importance should be attached to this point.

BREED AS A FACTOR IN GROWTH

Many characteristics of great interest to the breeder and of wide practical importance are typical of certain breeds and are so closely involved with the hereditary factors of the breed as to be transmitted with reasonable certainty. For this reason it is of interest to examine the data on growth to determine to what extent breed is involved as a factor. Data covering this point are given in Table 8. These data are based upon measurements and weights that have been taken during the investigation already described which concerns the normal rate of growth of dairy animals. Altho incomplete, sufficient data are already at hand to make possible a fairly accurate statement of the influence of breed on the rate of growth and time of maturity. The data are taken from purebred animals kept under what is considered normal conditions. The height measurements were taken monthly until the rate of growth became very small and from then on at longer intervals. The Jerseys were measured monthly until 24 months old, after this when they were 27, 30, 33, 36, 42, 48 and 50 months old. The measurements were continued monthly for

TABLE 8.—NORMAL GROWTH OF THE JERSEY AND HOLSTEIN BREED IN HEIGHT AND WEIGHT

Age	Height		Weight	
	Jerseys	Holsteins	Jerseys	Holsteins
Month	cm.	cm.	lbs.	lbs.
Birth	66.1	71.8	53	90
1	70.3	76.8	76	121
2	74.7	82.0	105	157
3	79.3	86.8	140	200
4	83.9	92.0	174	249
5	89.3	96.5	222	302
6	93.7	100.9	266	349
7	96.8	104.0	302	389
8	99.8	107.1	340	425
9	102.8	109.1	376	466
10	105.0	111.3	407	501
11	106.5	112.6	432	529
12	108.3	114.0	456	558
13	110.1	115.7	480	574
14	111.4	117.4	503	596
15	112.7	118.8	528	612
16	113.4	120.3	533	643
17	114.6	121.3	553	660
18	115.6	121.8	572	686
19	116.8	122.7	598	715
20	117.5	123.8	621	747
21	117.9	123.9	649	774
22	119.1	124.9	668	796
23	119.8	125.7	689	824
24	120.4	126.5	716	841
25	....	127.6	737	869
26	....	128.2	...	893
27	121.9	129.3	...	927
28	....	129.8	...	...
29	....	130.5	765	...
30	122.9	130.7	...	...
31	....	....	...	971
33	123.2	132.2	...	...
35	....	....	779	...
36	124.1	132.8	...	...
37	....	....	...	1055
42	124.4	133.5	...	...
44	....	....	870	1098
48	125.6	135.1	...	....
50	....	....	843	1132
54	....	135.8	...	....
57	....	....	904	....
58	....	....	...	1219
60	125.6	136.5	...	....
64	....	....	...	1207

the Holsteins until they were 30 months old and after that at the same intervals as for the Jerseys.

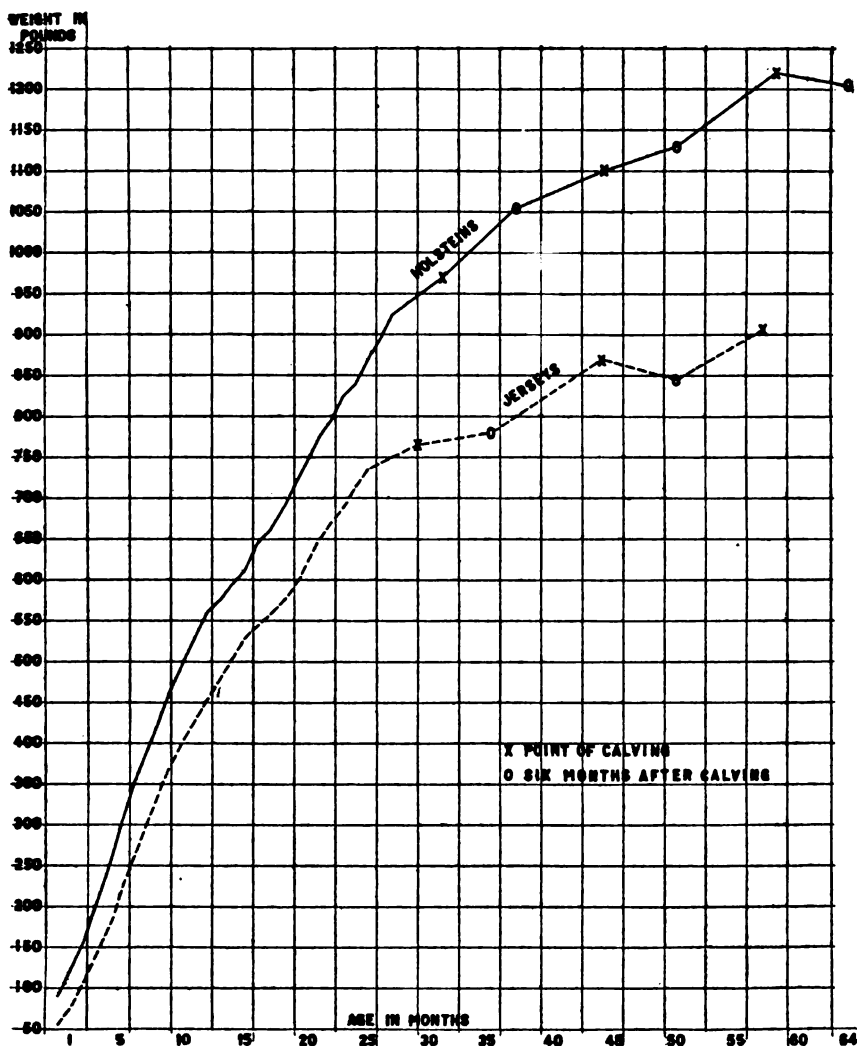


FIG. 4.—The relation of breed to growth as represented by weight. Holsteins normally make somewhat more rapid growth in weight from birth and grow for a much longer period than Jerseys. Their greater size at maturity is the result of a combination of these two factors. The growth in weight of cows in milk can be represented most satisfactorily by using weights taken immediately after calving and six months later. (Table 8)

The weights were taken under controlled conditions for three days in succession at the middle point of each month. It is an exceedingly difficult matter to obtain a fair series of weights repre-

senting the life of a cow on account of the extreme variations due to pregnancy and lactation. The weights were taken according to the plan already described in detail. They were taken monthly up to the time of calving and for three days in succession following parturition, and again six months later. For this reason the weights given in the table appear to come at irregular intervals after the animal has passed the second year. The average age at first freshen-

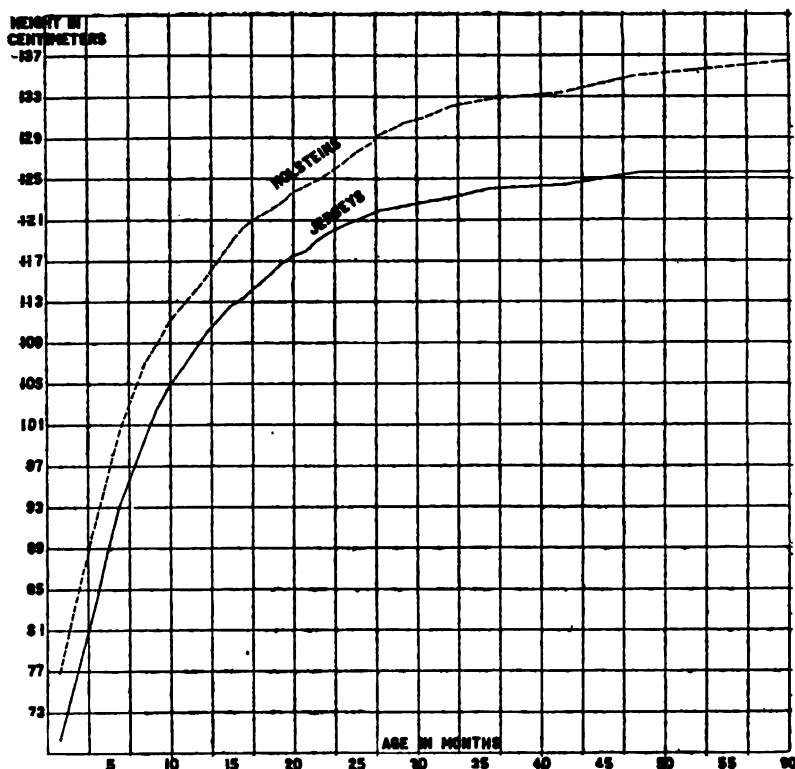


FIG. 5.—The relation of breed to skeletal growth. The difference in height between Jerseys and Holsteins at birth is 5.7 c. m. At the age of 24 months it is only 6.1 c. m. From this point the difference between them gradually increases. The greater size of Holsteins is due to a greater size at birth and to a prolonged period of growth. The amount of skeletal growth for Jerseys and Holsteins is almost exactly the same for the first two years. (Table 8)

ing of the Holstein group was 31 months and the average weight 971 pounds. Six months later the average weight was 1055 pounds. The average age at second calving was 44 months, the weight following calving 1098 pounds. The data are shown graphically in Figs. 4 and 5, and a summary which gives a comparison of the increase in height and weight for six-month periods is found in Table 9. The

TABLE 9.—COMPARISON OF NORMAL GAINS BY JERSEYS AND HOLSTEINS

	Jerseys		Holsteins	
	Increase in height	Gain in weight	Increase in height	Gain in weight
	cm.	lbs.	cm.	lbs.
Birth to 6 months.....	27.6	207	29.1	259
6 months to 12 months..	14.6	196	13.1	209
12 months to 18 months..	7.3	116	7.8	128
18 months to 24 months..	4.8	144	4.7	155
24 months to 36 months..	3.7	...	6.3	...
36 months to 48 months..	1.5	...	2.3	...
48 months to 60 months..	...	...	1.4	...

data show that the growth curve for the Jersey and Holstein breeds as indicated by height measurements is strikingly uniform until the animals are about 24 months old. There is a difference of 5.7 centimeters in height of the animals at birth and at 24 months old the difference is only 6.1 centimeters. From this point on the difference in height steadily increases because the Holstein animals continue to grow. Growth for this breed ceases at some point between 48 and 60 months, while that for the Jersey has practically ceased at four years. It has been generally recognized that the Holstein breed is slower in reaching maturity, but it has not been pointed out that the rate of growth is nearly the same for the two breeds during the first two years. From birth to 24 months the normal increase in height at withers for Jerseys is 54.3 centimeters and for Holsteins 54.7 centimeters. At 24 months the Jerseys have completed 91.2 per cent and the Holsteins 84.5 per cent of their total increase in height measurement. The greater size of skeleton of Holsteins at maturity as compared with Jerseys is not due to a greater rate of gain but to a greater size at birth and a more prolonged period of growth. In regard to weight, the Holsteins make somewhat greater gains from the first as seen in Table 8. At 24 months the Jerseys have reached 79 per cent and Holsteins 70 per cent of their mature weight. Animals of the Holstein breed also continue to increase in weight to an age beyond the point at which growth ceases with the Jerseys. On account of the great extremes in weight due to pregnancy and lactation it is very difficult to fix an age at which maximum weight is reached. It probably is not less than two years after

the skeleton ceases to grow. Figure 13 shows typical weight curves for two groups of Jerseys from a point several months before the first freshening until after the third freshening for the early-calving group which averaged 22.7 months at first parturition, and until after the second parturition for the group which calved at an average age of 34.9 months. From Table 8 it appears that Jersey cows continued to increase in weight at least up to nearly six years of age. The data for the Holsteins do not extend far enough to make clear the limits of their increase in weight. Other data available show that the maximum weight is attained, usually when the animal is about seven years old. This increase in weight after the skeleton ceases to grow must be largely muscle and tissue. It is questionable if this gain can be attributed to an accumulation of fat, since the animals were maintained as nearly as possible in the same condition of flesh from year to year. In this respect the growth of cattle is similar to that of man. It is well known that weight in man does not reach the maximum until long after growth in stature has ceased.

Liberality of the ration.—It is a well-known fact that the rate of growth of an animal is dependent to a considerable extent upon the amount of nutrients received. Observing stockmen have long known that the time of maturity of an animal is hastened by liberal feeding and delayed by scant feeding. It is also a common, altho not universal, belief among stockmen that liberal feeding of the young animal results in a larger animal at maturity. Concerning this point probably the correct view is, that with sufficient feed it is possible for the animal to grow to the full extent of its inheritance, while insufficient feed may cause the animal never to reach the full development made possible by its inheritance. Data concerning the effect of the liberality of the ration are given in Tables 10 and 11. Full details concerning the rations given these animals are found in Bulletin 135 of the Missouri Experiment Station. It is sufficient to say here that the heavy-fed group received whole milk and practically all they would consume of a grain mixture composed of corn and oats, with alfalfa hay for roughage. The light-fed group received skim milk during the first six months and alfalfa hay, and in some cases pasture, but no grain up to the time of first calving. After calving both received the same ration which was the one fed to the milking cows in the herd.

There seems no doubt that all requirements of a ration for growth were met with both groups, and that the only difference of importance was in the total nutrients received.

TABLE 10.—INFLUENCE OF RATION UPON RATE OF GROWTH—HEIGHT AT WITHERS

Age	Holsteins		Jerseys	
	Heavy-fed	Light-fed	Heavy-fed	Light-fed
months	cm.	cm.	cm.	cm.
1	76.7	75.6	70.1	71.6
2	81.7	80.4	73.1	75.9
3	88.1	84.6	77.9	80.5
4	93.6	88.6	83.6	84.2
5	99.7	93.7	88.6	87.9
6	103.4	96.7	92.7	92.3
7	106.2	98.2	96.5	93.9
8	108.7	99.7	99.4	95.2
9	111.5	101.2	102.2	97.2
10	113.5	102.7	105.0	99.1
11	115.8	104.5	107.3	101.4
12	117.8	106.3	108.8	102.5
13	119.2	107.6	110.7	103.9
14	120.8	109.2	112.4	105.3
15	122.3	110.8	114.2	106.3
16	123.8	113.0	114.5	107.8
17	124.9	113.8	115.7	109.2
18	125.4	115.3	116.6	110.6
19	126.9	116.6	118.8	112.3
20	127.9	117.4	119.8	113.2
21	128.5	118.6	120.5	114.1
22	129.1	119.7	120.9	114.9
23	129.5	121.1	121.4	115.9
24	130.1	121.6	121.8	116.3
25	130.7	122.6	122.0	116.6
26	131.2	123.6	122.9	117.0
27	131.6	123.9	123.1	117.6
28	131.9	124.5	123.4	118.0
29	132.3	124.9	123.8	119.0
30	132.6	125.6	124.2	119.5
36	133.7	126.9	125.1	121.9
42	134.7	128.5	....	121.9
48	134.9	129.5	125.7	123.0
60	135.9	130.3	125.9	123.0

TABLE 11.—INFLUENCE OF RATION UPON RATE OF GROWTH—WEIGHT

Age	Holsteins		Jerseys	
	Heavy-fed	Light-fed	Heavy-fed	Light-fed
months	lbs.	lbs.	lbs.	lbs.
1	113	104	66	87
2	139	137	88	109
3	212	177	119	137
4	263	214	161	173
5	362	258	203	211
6	418	292	248	245
7	455	307	285	261
8	490	326	321	279
9	545	344	357	295
10	591	372	393	312
11	628	382	436	336
12	659	404	463	363
13	714	431	504	378
14	737	463	540	404
15	776	491	579	431
16	819	519	628	455
17	852	535	667	477
18	891	569	708	495
19	932	588	744	515
22	938	666	772	568
28	1036	745	842	664
34	1094	866	890	734
40	1070	883	884	743
46	1122	946	904	801
54	1119	968	907	822
54-66	1290	1065	937	880
66-78	1265	1113	975	851
78-90	1191	....	1006	922

The results given in Tables 10 and 11 are illustrated in Figs. 6 and 7. It is seen that the Holstein groups started at practically the same height at 1 month, and that the spread between the curves shows a sudden increase beginning at six months. This is clear with both the Jersey and Holstein groups and is to be attributed to the fact that milk was dropped from the ration at this point. The light-fed group from then on received roughage only until first parturition. As a result they did not consume a sufficient amount to supply nutrients equal to those received by the heavy-fed group which consumed a heavy grain ration during this period.

The difference in the height of the two groups increased gradually until the maximum was reached at 19 months for both the Jerseys and the Holsteins. From this point on the difference be-

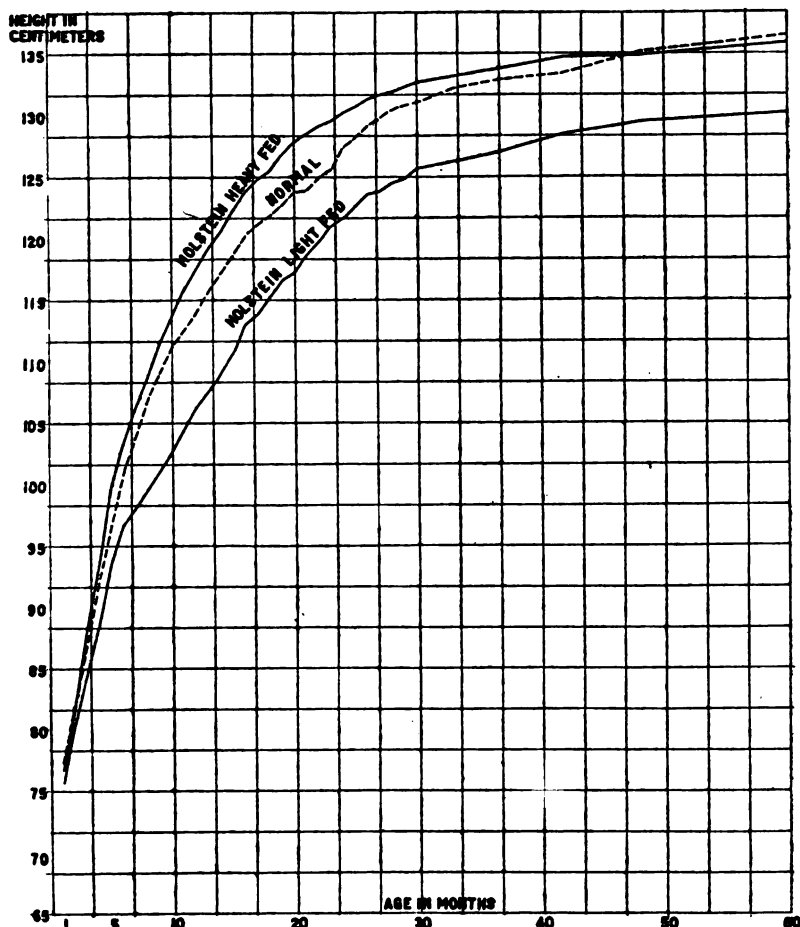


FIG. 6.—The liberality of the ration as a factor in determining the skeletal growth of Holsteins. Beginning at 6 months of age when milk feeding was stopped the light-fed group began to fall below the normal. At five years of age, when skeletal growth had ceased, they were still considerably undersized. The heavy-fed group were somewhat above normal in size, especially between the ages of 10 and 30 months. At 5 years of age when skeletal growth had ceased, they were practically normal. (Table 10)

comes less marked, which means that the light fed group continued growing over a somewhat longer period than was the case with the group which received the heavy ration. At no time, however, did the light-fed group in either the Holstein or Jersey breed reach the

size of the heavier-fed group. At 60 months, when the Holsteins had reached maturity, so far as growth of skeleton is concerned, the heavy-fed group had an average height of 5.6 centimeters in excess of the light-fed group; while with the Jersey breed the difference was 2.0 centimeters.

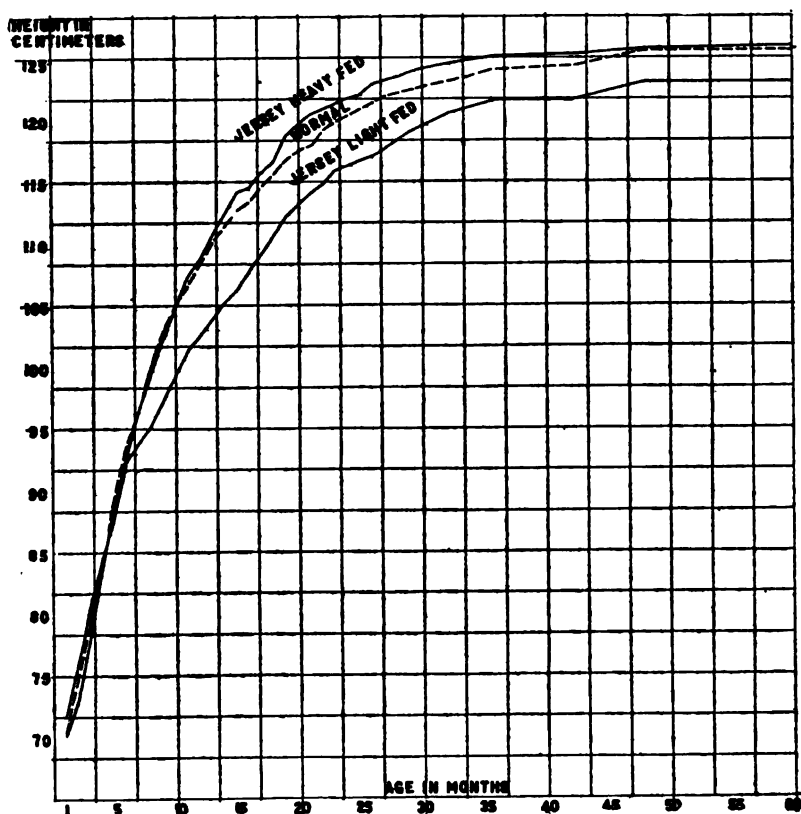


FIG. 7.—The liberality of the ration as a factor in determining the skeletal growth of Jerseys. Results with Jerseys are almost identical with those shown for Holsteins in Fig. 6. The light-fed group began to fall below normal when milk was taken from the ration at 6 months of age. At 5 years, nearly one year after skeletal growth had ceased, this group was 2.6 c. m. below the normal. The heavy-fed group passed the normal at 10 months and at maturity remained slightly above. (Table 10)

As shown in Figs. 6 and 7 the heavy-fed groups more nearly approached the normals for the breeds. In the case of the Holsteins the mature size was even slightly below the normal. It is clear from these figures that the light-fed groups, as a result of the feed which they received when young, never reached the normal size. This

bears out the fact that the conditions of nutrition during growth may result in the size at maturity being below normal; and that high nutrition increases the rate of growth to a considerable extent, but cannot stimulate growth beyond the maximum inheritance of the animal. These results also illustrate the fact earlier mentioned that a very liberal ration shows a greater relative effect upon the increase in weight than on the skeleton growth. This fact is made clear in Table 12

TABLE 12.—COMPARISON OF EFFECT OF RATIONS UPON SKELETON GROWTH AND INCREASE IN WEIGHT IN PERCENTAGE OF THE NORMAL

	Jerseys		Holsteins	
	Light-fed	Heavy-fed	Light-fed	Heavy-fed
	Weight lbs.	Weight lbs.	Weight lbs.	Weight lbs.
6 months	95	99	85	120
12 months	80	104	73	118
18 months	83	128	84	130
24 months	84	109	88	119
	Height cm.	Height cm.	Height cm.	Height cm.
6 months	98	99	96	102
12 months	95	101	93	103
18 months	95	102	95	103
24 months	96	101	97	103

in which the data are expressed for the four groups in terms of percentage of the normal. At 18 months the light-fed Jerseys showed 83 per cent of normal growth in weight and 95 per cent in height and the Holsteins at the same age 84 per cent in weight and 95 per cent in height. The heavy-fed Jerseys at the same age were 128 per cent of normal in weight and 102 per cent in height, and the heavy-fed Holsteins were 130 per cent in weight and 103 per cent in height. These data show in general that a more liberal ration tends to materially increase the rate of gain, especially in weight, and as a result maturity is reached at an earlier age. The growth rate of the animals on the lighter ration is slower and somewhat prolonged, but the size at maturity is not equal to that attained by those which received a heavier ration. The earlier maturity of the animal is shown not alone by size but also by earlier sexual maturity, data on which has been given in the earlier publication.¹²

GESTATION

Investigations by one of us already published¹³ show that the tax upon the cow in the way of nutrients necessary to develop the fetus is too small to be of any special significance from the standpoint of animal feeding. It was found that a ration which was just sufficient to maintain a cow at uniform weight when dry and farrow was also sufficient, if fed thruout the period of gestation, to maintain the cow at normal weight and to develop a normal fetus. The probable explanation of this result is the small amount of dry matter which the fetus contains. These data show that an average Jersey calf at birth, including amniotic fluids and placenta, contains only about 20 pounds of dry matter. It was pointed out that under abnormal conditions of feeding, gestation might prove to be a much more serious tax on the cow than was shown in investigations where, so far as present knowledge goes, the rations supplied everything needed for both growth and maintenance. The results of the investigations with growing heifers herein reported are consistent with those to which reference has already been made.¹⁴ Practical breeders of dairy cattle, because of the supposed tax upon the animal involved by gestation, often emphasize strongly the value of liberal feeding of the pregnant animal. Practice has fully justified liberal feeding of the pregnant dairy cow. Its value, however, is not so much for the sake of the growing fetus, as is often assumed, but rather to insure that the cow herself will have the necessary reserve of nutrients and possibly of mineral matter, according to the investigations of Forbes, to enable heavy milk production to be sustained. The practical dairy cattle breeder has likewise over emphasized the influence of gestation upon the growth of heifers. Experienced breeders of dairy cattle know that a heifer calving at a very early age and once each year thereafter does not, as a rule, reach the same size as one which is more mature before the time of first freshening. The error commonly made is that of attributing the check in growth and failure to attain normal size at maturity to the strain of pregnancy, when properly it should be attributed to the strain of milk production. Data on the relation of gestation to growth are given in Tables 13, 14, 15 and 16.

TABLE 13.—INFLUENCE OF GESTATION ON GROWTH OF DAIRY HEIFERS

	Light-fed				Heavy-fed			
	Pregnant		Not pregnant		Pregnant		Not pregnant	
	height	weight	height	weight	height	weight	height	weight
Months from calving	cm.	lbs.	cm.	lbs.	cm.	lbs.	cm.	lbs.
<i>Jerseys</i>								
9	106.3 ¹	432	108.2 ²	490	111.1 ³	484	109.5 ⁴	487
8	108.2	458	109.0	514	113.3	532	112.5	521
7	109.5	478	110.6	513	114.5	569	114.3	557
6	110.7	497	112.1	515	116.0	614	115.5	599
5	111.2	525	113.5	538	117.7	658	116.9	633
4	112.6	544	114.0	561	118.4	666	117.3	670
3	113.7	566	115.7	576	118.7	716	117.9	696
2	114.3	582	117.0	592	119.5	753	118.7	721
1	115.1	606	117.3	616	120.2	787	119.7	724
1 ⁵	115.3	556	117.2	619	120.1	737	119.9	747
<i>Holsteins</i>								
9	....	608 ⁶	....	564 ⁶	118.9 ⁷	707	119.3 ⁸	696
8	....	667	....	572	120.5	734	120.3	747
7	....	699	....	585	121.6	784	122.1	770
6	....	760	....	626	122.7	814	123.5	816
5	....	786	....	644	124.5	854	124.3	852
4	....	803	....	682	125.4	889	125.4	884
3	....	826	....	709	126.0	931	126.6	928
2	....	863	....	725	126.8	970	128.0	973
1	....	890	....	743	127.9	1021	128.9	1009
1 ⁹	....	820	....	748	128.1	882	129.8	1020

1. Average for six animals.
2. Average for four animals.
3. Average for three animals.
4. Average for five animals.
5. Average for two animals, the height measurements are incomplete.
6. Average for five animals.
7. Average for four animals.
8. Average for four animals.
9. Immediately following parturition for pregnant group and at same age for non-pregnant group.

TABLE 14.—COMPARISON OF GAINS IN HEIGHT AND WEIGHT PREGNANT AND NON-PREGNANT HEIFERS DURING GESTATION PERIOD OF PREGNANT GROUP

	Increase in height	Gain, weights one month be- fore calving	Gain, weights after calving	Gain, weights after calving plus weight of calf
	cm.	lbs.	lbs.	lbs.
Jerseys light-fed				
Pregnant ...	8.8	174	124	168
Check group				
not pregnant...	9.1	126	129	129
Jerseys heavy-fed				
Pregnant ...	9.1	303	253	291
Check group				
Not pregnant...	10.2	237	260	260
Holsteins light-fed				
Pregnant ...	...	282	212	280
Check group				
not pregnant...	...	179	184	184
Holsteins heavy-fed				
Pregnant ...	9.0	314	175	253
Check group				
not pregnant...	9.6	313	324	324

TABLE 15.—INFLUENCE OF GESTATION UPON GROWTH—JERSEY HEIFERS ON NORMAL RATIONS

Age	Four heifers average age at calving 26 months		Four heifers average age at calving 35 months	
	Height	Weight	Height	Weight
Months	cm.	lbs.	cm.	lbs.
17	114.6	554	115.1	564
18	117.7	583	117.2	610
19	116.9	615	117.6	618
20	117.3	646	117.7	637
21	118.3	669	118.1	644
22	119.2	691	120.0	674
23	119.5	727	120.6	686
24	119.8	757	121.1	719
25	120.2	791	121.5	716
26	120.6	824	121.8	733
Weight after calving	....	729	....	...

TABLE 16.—INFLUENCE OF GESTATION UPON GROWTH—MEASURED BY HEART GIRTH AND WIDTH OF HIPS

Months previous to parturition	Average heart girth		Average width at hips	
Pregnant group	Ten pregnant heifers	Ten non-preg- nant heifers	Ten pregnant heifers	Ten non-preg- nant heifers
	cm.	cm.	cm.	cm.
8	142.6	142.6	38.0	37.5
7	145.2	145.4	39.3	38.2
6	148.0	148.2	40.3	39.1
5	151.2	150.6	41.1	40.0
4	152.8	153.6	41.6	40.8
3	154.8	155.2	42.5	41.6
2	156.4	157.7	43.1	42.6
1	158.4	160.7	44.1	43.8
0	161.5	163.5	44.7	44.6

Table 13 gives the data for height at withers and weight for Holsteins and Jerseys which received both heavy and light rations up to calving time. As stated in a previous paragraph, one group of animals received a heavy and the other a light ration up to calving. These were sub-divided into two groups with reference to age at first calving. One-half of each main group were bred to calve when 20 to 24 months old, and the remainder when 30 to 36 months old. The comparisons made in Table 13 are between the pregnant animals and the non-pregnant animals which received the same ration and which were the same age. Figs. 8 and 9 combine the data from the heavy and light-fed groups. Table 14 gives a summary of the data in a form which is more readily studied. The height figures seem to show a slight tendency for gestation to check growth. The light-fed Jerseys, for example, showed an average growth of 8.8 centimeters for the pregnant group and 9.1 centimeters for the open group. In each of the three comparisons, slightly greater growth was made by the open group.

Weights taken on pregnant animals one month before parturition in every case were higher than those for the non-pregnant animals. If the weights of the pregnant group taken immediately after parturition are compared with the open group the advantage is with the latter. If the weights of calves born are added to that of the cows taken following parturition, then in three out of four comparisons the combined figure exceeds that of the open group.

Table 15 shows data taken on an entirely different group of animals, those used in the investigations to determine normal growth, reference to which was made in the paragraph concerning source of data. It was possible to select data from four animals that calved

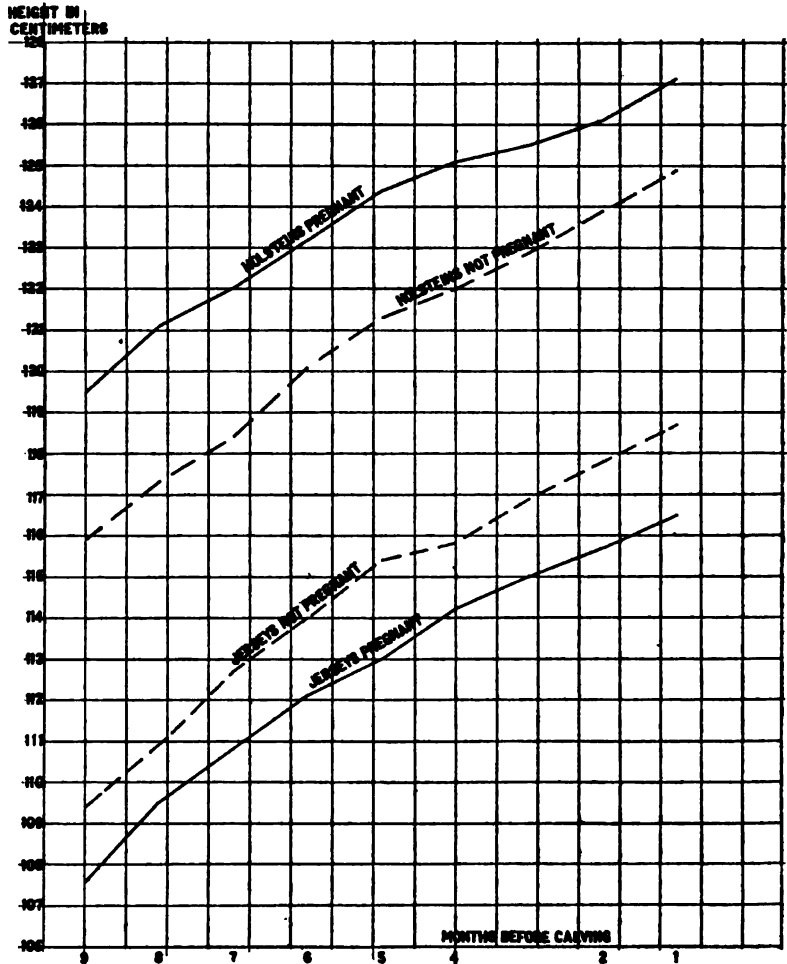


FIG. 8.—The influence of gestation upon skeletal growth. Pregnancy has very little effect upon the skeletal growth of dairy animals. Figure 8 is a combination of values given in Table 13 for heavy- and light-fed Holsteins and heavy- and light-fed Jerseys

at an average age of 26 months for comparison with that from an equal number calving at an average age of 35 months. The data show that the pregnant animals gained 6 centimeters in height during the period of gestation, and the open group 6.7 centimeters dur-

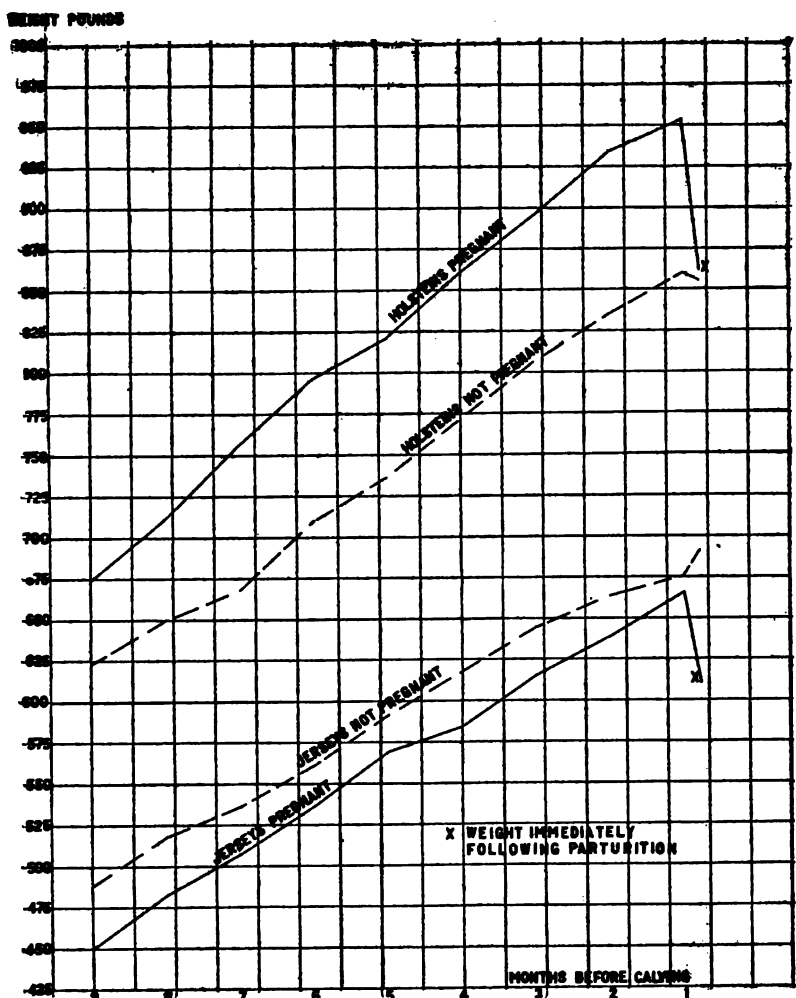


FIG. 9.—The influence of gestation upon weight. Pregnancy has a very little effect upon the actual growth of dairy animals. Figure 9 is a combination of values given in Table 13, for heavy- and light-fed Holsteins and heavy- and light-fed Jerseys

ing the same length of time at the same age. Altho the pregnant group lost 95 pounds as a result of parturition, the total gain by this group from the time of breeding until after parturition was still greater than that of the open group during the same period. These data are entirely consistent with those given in Table 13.

Table 16 gives the average increase in heart girth and width at hip of a group of ten heifers during gestation, and of the same

number of open heifers of the same age and on the same ration. The animals are the same ones which supply the data in Table 13. During the nine months the pregnant animals increased 18.9 centimeters in heart girth and the open heifers 20.9 centimeters. In width of hip, the pregnant group increased 6.7 centimeters and the open group 7.1 centimeters. The results apparently show, as does Table 13, a slight check on skeleton growth due to gestation. However, the check is so small that it could not be observed at all and only shows up when accurate measurements are made.

The general conclusion from the data given is that gestation does exert a measureable effect upon skeleton growth of dairy heifers, but the check is so slight that for all practical purposes it may be entirely ignored. If the growth of the animal is measured by weight, no check is found which is due to gestation. Pregnant animals shortly before parturition will outweigh open animals of the same age which have received the same ration. Weights taken following parturition show little difference between groups which have developed the fetus and the open groups of the same age.

THE INFLUENCE OF LACTATION UPON GROWTH

Aside from the character of the ration, gestation and lactation are the most important factors to be considered in connection with growth. As indicated, gestation is a factor of little importance in this connection, due probably to the very small tax upon the animal which results from the development of the fetus. However, as soon as lactation begins the situation is different.

Table 17 gives data taken from the investigations concerning the growth and development of dairy heifers to which reference has already been made. One group was bred to calve at an early age, 20 to 24 months, and the other group at what would be called a late age, 30 to 36 months.

The figures given in Table 17 represent the height and weight of the animals in milk as compared with the group not in milk but of the same breed and consuming the same ration as that received by the group in milk before freshening.

The weights given after calving for the group not in milk are those following the first parturition for this group; but because the first calving by this group did not come at an age exactly comparable with the second calving of the first group, it is not possible to give a complete set of weights for the group not in milk. The weights given are for comparable ages. The data in this table concerning growth in height are given graphically in Figs. 10 and 11.

TABLE 17.—INFLUENCE OF LACTATION UPON GROWTH OF DAIRY HEIFERS

	Group 1 Heifers in milk		Group 2 Heifers not in Milk	
	Height at withers	Weights	Height at withers	Weights
Jerseys light-fed	cm.	lbs.	cm.	lbs.
Month before calving (Group 1)	115.1	606	117.3	616
Month after calving (Group 1)	115.3	556	117.2	619
	114.8	554	118.8	656
	115.5	569	119.3	700
	116.3	586	119.9	746
	116.6	593	121.1	...
	117.0	619	122.1	...
	117.8	626	122.9	...
	118.4	646	122.5	...
	118.9	665	122.8	...
	119.2	684	123.0	...
	119.5	706	123.5	...
Month before 2nd calving (Group 1)				
1) 1st calving (2nd Group)....	120.3	730	123.9	...
After calving	120.3	686	124.1	805
Jerseys heavy fed				
Month before calving (Group 1)	120.2	787	119.7	724
Month after calving (Group 1)	120.1	737	119.9	747
	120.2	726	120.5	782
	120.5	704	121.8	808
	121.7	706	122.1	824
	121.8	700	123.0	847
	122.3	702	123.1	852
	122.5	720	123.7	882
	122.8	734	124.1	886
	123.8	766	124.6	...
	123.5	747	124.5	...
	124.2	798	124.7	...
Month before 2nd calving (Group 1)				
1) First calving (Group 2)....	124.0	828	125.0	...
Month after calving	124.0	741	125.8	981
Holsteins heavy-fed				
Month before calving (Group 1)	127.9	1021	128.9	1009
Month after calving (Group 1)	128.1	882	129.8	1027
	128.3	905	130.1	1058
	128.7	883	130.6	1109
	128.9	897	131.9	1134
	129.4	883	132.5	1162
	129.9	869	132.8	1179
	129.9	902	133.0	....
	130.6	921	134.0	....
	131.3	955	134.1	....
	131.4	988	134.2	....
	131.5	1023	134.4	....
Month before 2nd calving (Group 1)				
1) 1st calving (Group 2).....	131.8	1052	134.8	1225
After calving	131.8	961	135.0	1225

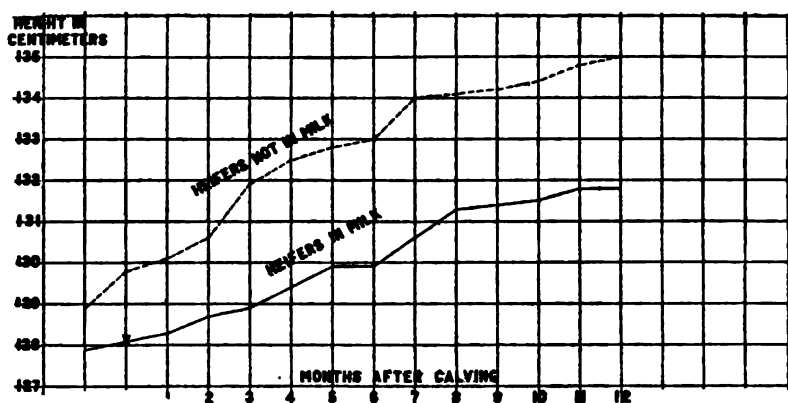


FIG. 10.—The influence of lactation upon skeletal growth. These data represent a group of heavy-fed Holsteins. One month before calving the non-pregnant group averaged 1 c.m. taller than the pregnant group. Twelve months after the calving of the pregnant group the late calving group was on the average 3.2 c.m. taller. In contrast to pregnancy, lactation exerts a strong influence upon growth. (Table 17)

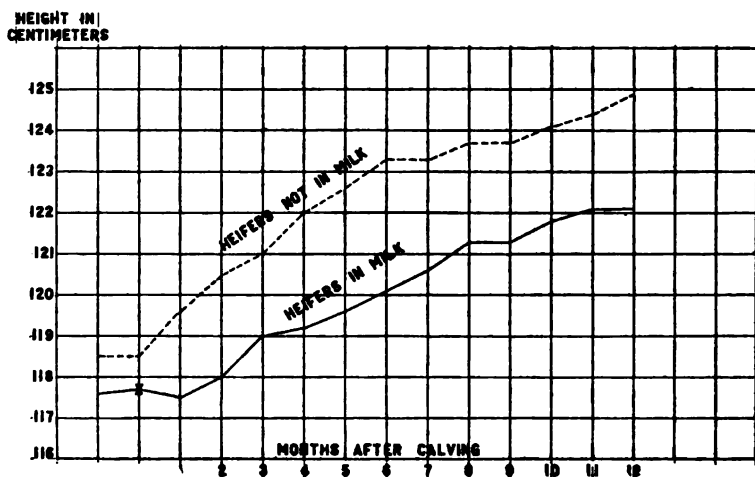


FIG. 11.—The influence of lactation upon skeletal growth. This figure is based upon combined data for groups of heavy- and light-fed Jerseys. The results are almost identical with those for Holsteins given in Figure 10. (Table 17)

These data show clearly that the skeleton growth is considerably checked by lactation. The light-fed Jersey group, for example, shows a growth of 5.2 centimeters in height at withers and the group not in milk 6.8 centimeters. The group of Jerseys which received the heavy ration previous to calving made a growth of 3.8 centimeters in height during the lactation period, while those of the group not in milk gained 6.1 centimeters.

The difference in the gains in weight are even more significant, as would be expected. The Jersey group which calved early weighed 606 pounds before first calving and the group which calved late weighed 616 pounds. The group in milk weighed 686 pounds after the second calving, a gain of only 80 pounds. The group which calved late weighed 616 pounds at the time the early calving group freshened the first time, and weighed 805 pounds after calving, which makes a gain of 189 pounds as compared to a gain of 86 by the group in milk.

This group which received the heavy ration up to first calving actually weighed 46 pounds less after the second calving than before the first, while the heavy-fed group not in milk during the period gained 257 pounds. Similar results are found for the Holsteins.

Tables 18 and 19 give data regarding the influence of the age at first calving upon the growth of the animal, not only during the

TABLE 18.—INFLUENCE OF AGE AT FIRST CALVING ON GROWTH

Age	Light-fed Jerseys		Heavy-fed Jerseys	
	Early calving seven animals	Late calving five animals	Early calving four animals	Late calving five animals
Months	Height cm.	Height cm.	Height cm.	Height cm.
19	111.1	113.6	119.5	118.1
20	112.2	114.3	120.5	119.1
21	112.4	115.8	120.7	120.3
22	113.4	116.4	121.4	120.4
23	114.4	117.4	121.5	121.3
24	114.8	117.8	121.6	122.0
27	115.6	119.7	122.6	123.7
30	117.1	122.0	124.0	124.5
36	119.6	124.2	124.1	126.1
42	119.8	124.1	124.6	126.3
48	121.4	124.6	124.7	127.0
60	121.3	124.6	124.7	127.2
Age	Weights	Weights	Weights	Weights
Month	lbs.	lbs.	lbs.	lbs.
19	504	524	759	732
22	556	587	758	782
28	614	740	726	934
34	687	806	740	981
40	705	800	839	911
46	775	827	850	937
54	763	882	864	924
66	866	895	889	984
78	865	928	...	...

TABLE 19.—INFLUENCE OF AGE AT FIRST CALVING ON GROWTH—HEAVY-FED HOLSTEINS

Age	Early calving four animals	Late calving five animals
Months	Height cm.	Height cm.
19	126.5	127.3
20	126.8	128.9
21	127.8	129.2
22	128.2	130.0
23	128.6	130.3
24	128.9	131.2
27	130.1	133.0
30	131.3	133.9
36	131.9	135.6
42	133.2	136.1
48	133.7	136.0
60	134.1	137.6
Age	Weights	Weights
Months	lbs.	lbs.
19	942	922
21	883	994
27	888	1184
34	963	1225
40	1011	1129
48	1105	1139
54	1118	1121
..
66	1214	1299
78	1221	1280

first lactation period but until maturity is reached. These data are represented in Fig. 12.

The animals supplying these data are a portion of those which supplied the data in Table 17. All the animals could not be used, since the data did not cover a sufficiently long period of time.

It will be noted in the case of the light-fed Jerseys at nineteen months old that the late calving group was 2.5 centimeters taller at the withers than the early calving group. By the time they were 27 months old the difference was 4.1 centimeters, at 36 months 4.6 centimeters, and when maturity was reached at 60 months the difference was 3.3 centimeters, indicating that the early calving animals

were permanently retarded in growth. The same table gives similar data for the heavy-fed Jerseys. At 19 months, the early calving were 1.4 centimeters taller than the late calving group, but at 27 months the conditions were reversed and the late calving group were 1.1 centimeters taller. At 36 months, the difference was still more marked, while at maturity the late calving group was 2.5 centimeters taller. This is a gain of 3.9 centimeters over that made by the early calving group.

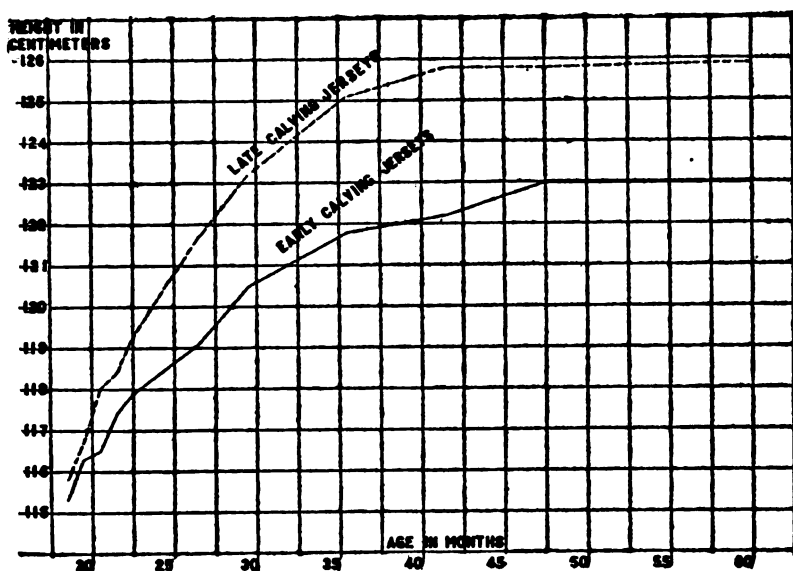


FIG. 12.—The influence of lactation upon skeletal growth. This figure is based upon combined data for groups of heavy- and light-fed Jerseys. The data cover the entire growing period of the animal and show that the early calving group is 2.9 c.m. below the later calving group in height at withers at maturity. (Table 18)

Table 19 shows similar results for the height measurements of the Holsteins. When 19 months old the late calving group was 0.8 centimeter higher than the early calving group. At 27 months this difference had increased to 2.9 centimeters, and at maturity to 3.5 centimeters.

A study of the weights as given in Tables 18 and 19 shows similar results.

The late calving light-fed Jerseys averaged 928 pounds when 78 months old in contrast to 865 pounds for the early calving group. In the heavy-fed Jersey group, altho the late calving animals averaged 27 pounds lighter at 19 months, at maturity they were practically

100 pounds heavier than the early calving group. When 19 months old the early calving group of Holsteins averaged 942 pounds and were 22 pounds heavier than the late calving group. At 78 months the conditions were reversed and the late calving animals averaged 60 pounds heavier than the early calving group. These data show conclusively that lactation is a strong factor affecting growth, since skeleton growth continues at practically a normal rate unless acted upon by some strong factor.

The effect of lactation is not limited to a retardation of growth for a short time, but it is so marked that the final size of the animal at maturity is influenced to some extent by the age at first freshening. This is clearly shown by Tables 18 and 19. These data show that heifers which calve at an early age are generally smaller when mature than those animals which calve for the first time after they are more mature.

The relation of lactation to growth of the heifer is illustrated perhaps to best advantage in Fig. 13.

The weights are given for the early calving group from 9 months previous to the first calving thru two lactation periods and to the point following the third parturition. The late calving group is given at ages corresponding to the early calving group. The data for the individuals are arranged so that the calving points coincide. This figure shows that gestation did not depress the rate of gain. After parturition the early calving group naturally showed a drop in weight which continued for a month, after which there was a fairly constant gain, the rate increasing as the time of second parturition approached.

Following the second parturition the weight again declined and more time elapsed before a gain began. The curve of gain from this point up to third parturition is practically the same as between the first and second parturitions.

The late calving group made far greater gains than did the early calving group during the period which the latter were in milk. After the first parturition by the late calving group the curve of gain is much the same as for the early calving group. It will also be seen that the lead in weight made by the late calving group was still maintained altho not with so wide a variation after the second parturition which coincides with the third for the early calving group.

A study of the data presented leads to the conclusion that lactation is a severe tax upon the growth of a dairy heifer even when the

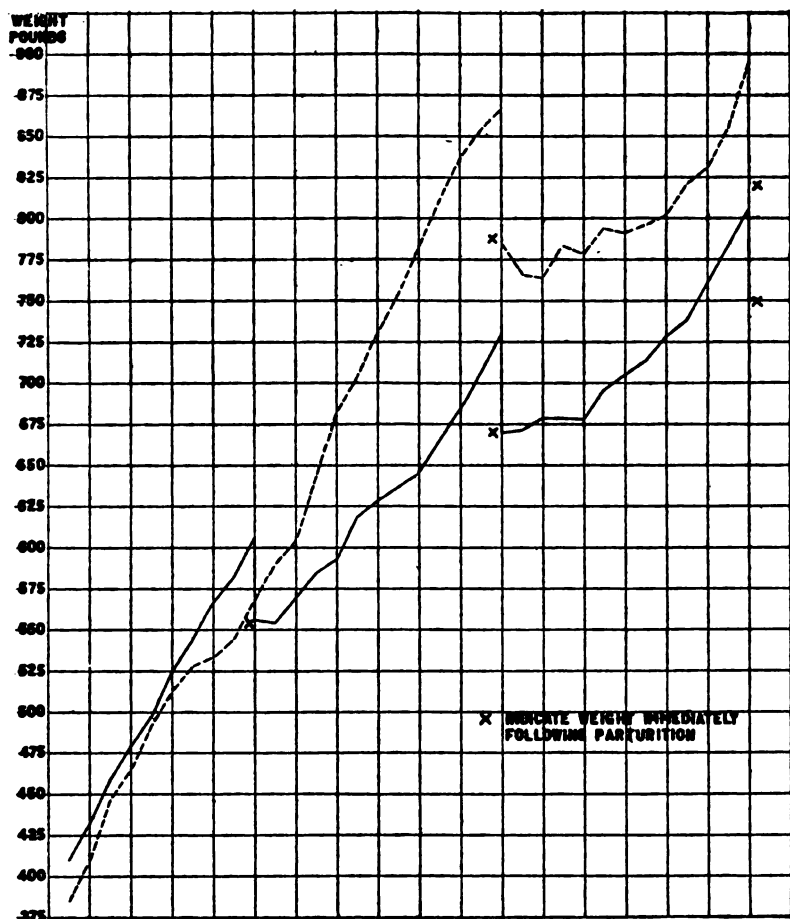


FIG. 13.—The influence of lactation upon growth as represented by weight. The solid line represents a group that calved first at an average age of 22.7 months, the dotted line represents a group that calved for the first time at an average age of 34.9 months, which was practically the same age at which the early calving group dropped their second calves. Note gestation rather increased than decreased the gain in weight but lactation was a decided check. The early calving group weighed 670 pounds after the second parturition and the late calving group 750 after their first. The early calving group regained part of this loss between the second and third parturition but never reached the weights of the late calving group

ration received is ample. Even under favorable conditions of feed and environment the heifer that comes into milk while still considerably short of maturity will not attain as large a size as the animal which is more mature before lactation begins.

The cause of the pronounced effect of lactation upon growth is undoubtedly to be found in the large amount of solids produced in the form of milk by the dairy cow. Even a mediocre heifer which gives no more than 20 pounds of milk daily with a total solid percentage of 12.5 is producing 2.5 pounds of dry matter daily. This is equal to the dry matter in 3.33 pounds of gain on a steer, assuming this gain to contain 75 per cent of dry matter.

If the same calculations are made for a heifer producing fifty pounds or more of milk daily, as is often the case with high bred cattle, it is easy to understand why lactation is a strong tax upon the growing animal.

COMBINED EFFECT OF LACTATION AND RATION

The data presented show clearly that liberality of feeding and age at first calving are both factors which exert considerable influence both upon the rate of growth and the size of the cow at maturity. The most pronounced results would naturally follow a combination of the two. In Table 20 and Fig. 14 are data showing

TABLE 20.—HEAVY RATIONS AND LATE CALVING OR LIGHT RATIONS AND EARLY CALVING

Age	Heavy-fed late calving Jerseys, height	Light-fed early calving Jerseys, height
Months	cm.	cm.
6	94.7	93.1
9	105.0	97.9
12	110.6	103.9
18	117.1	110.3
24	122.0	114.0
30	124.6	116.1
36	126.1	118.9
48	126.9	120.6

the combined effect of these two factors upon two groups of Jersey animals. Beginning at practically the same point at six months there was a constantly increasing difference in measurement up to thirty months. The margin decreased somewhat after this time altho at maturity there was still a difference of 6.3 centimeters in height, or about 20 per cent in total gain in height from the time the animals were six months old. It should be kept in mind also that the

light-fed early calving group, which fell so far behind in growth development received an ample ration after first parturition. Had the ration been deficient either in quantity or quality during lactation it is certain that the results would have been even more marked. While hereditary characteristics may in some cases be limiting factors in explaining the numerous undersized cows seen on many farms, it

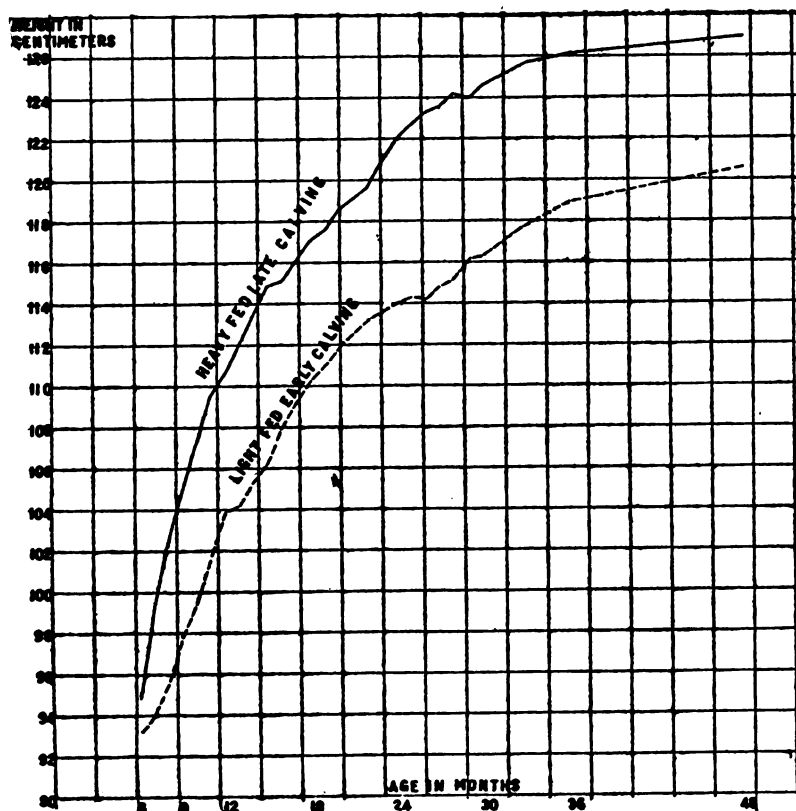


FIG. 14.—The combined influence of light feeding and early calving upon skeletal growth for Jerseys. The light-fed, early calving group was 1.6 c.m. below the other at 6 months while at 48 months, when skeletal growth for Jerseys is practically complete, the difference was 6.3 c.m. The combination of these two factors is a common cause of small cows frequently found in commercial herds. (Table 20)

is believed that the most important factors are a combination of early calving and a scanty ration during the growing period. While heredity is a factor in placing a high upper limit to the size of the large animals observed in some herds it is quite certain that, as a rule, a combination of rather late calving and liberal feeding when young are the more important factors.

HIGH CALCIUM VERSUS LOW CALCIUM RATIIONS

The data at hand do not contribute much to the fundamentals of this subject. However, they are of importance in connection with the applications of the laws of growth to domestic animals. The mineral constituents of the ration are looked upon now as more important factors than formerly. The old assumption was that domestic animals secured sufficient mineral matter from any ordinary ration. At present, as a result of the extensive investigations of Forbes, Hart and McCollum, and others, the tendency is to raise the question of possible deficiencies in mineral matter in rations of all farm animals. The data presented were taken in a preliminary trial conducted for the purpose of observing whether or not growing dairy heifers suffered from a deficiency of lime.

Two Jersey heifers were used. They were placed on experiment when approximately six months old and up to this time had received the usual skimmilk ration. The animal which received the low calcium ration was fed corn silage, or at times corn stover, and timothy hay for roughage, and corn and gluten meal for grain. It is unfortunate that the source of the ration was almost entirely the corn plant.

The animal which received the high mineral ration was fed alfalfa hay and a grain mixture composed of corn, wheat bran and a small amount of cottonseed meal. Both rations were carefully regulated to give an ample supply of energy and protein at all times. The calcium and phosphorous in the two rations can be compared from the data in Table 21 based upon analyses of the feeds used.

TABLE 21.—CALCIUM AND PHOSPHOROUS RECEIVED DAILY

Age	No. 85 Low mineral	No. 91 High mineral
Months	grams	grams
7 - 9	Ca 5.51 Ph 7.84	20.44 18.16
10 - 12	Ca 9.25 Ph 10.11	28.49 25.05
13 - 15	Ca 6.76 Ph 9.84	28.29 25.01
16 - 18	Ca 5.95 Ph 8.78	27.81 21.88

The animal on the low mineral ration, as far as could be determined by appearances, thrived and apparently was in a normal condition until she was nearly 18 months old and had been fed the ration for 13 months. She then began to show symptoms of an abnormal condition. The first indication was a stiffness in the joints and an abnormal gait in walking which gradually became worse until the animal walked with the knees partially bent and she could not get up from a lying position except with great difficulty. By making a decided change in ration and by giving bone meal liberally it was possible to restore the condition of this heifer to nearly normal within a month. The heifer which received the high mineral ration made excellent growth and remained in splendid physical condition at all times. The data in Table 22 give the normal height and weight

TABLE 22.—RELATION OF CALCIUM SUPPLY TO GROWTH

Age	Weight			Height		
	Normal weight	No. 85 low calcium ration	No. 91 high calcium ration	Normal height	No. 85 low calcium ration	No. 91 high calcium ration
Months	lbs.	lbs.	lbs.	cm.	cm.	cm.
6	260	...	205	93.7	....	92.0
7	302	263	234	96.8	....	94.0
8	340	271	272	99.8	98.0	97.5
9	376	323	308	102.8	99.5	99.5
10	407	374	344	105.0	102.5	102.8
11	432	419	379	106.5	105.0	105.0
12	456	456	406	108.3	106.0	106.5
13	480	485	421	110.1	110.3	108.0
14	503	526	450	111.4	109.3	108.8
15	528	547	483	112.7	111.3	109.0
16	533	562	501	113.4	110.5	111.0
17	553	582	532	114.6	112.5	113.3
18	572	589	555	115.6	115.0	115.0
19	598	...	572	116.8	116.5	115.8
20	621	...	591	117.5	117.5	117.5
21	649	...	615	117.9	118.0	117.5
22	668	...	634	119.1	119.5	118.5

for an animal of the Jersey breed and also the weight and height for the two experimental animals up to 22 months. The weight figures for the animal on the low mineral ration are given up to 18 months only, the point where the break down in condition occurred. The

same data are given graphically in Fig. 15. The result was that the animal which received the ration low in calcium made a perfectly normal growth both in height and weight and made a growth equal to the animal receiving the high mineral ration.

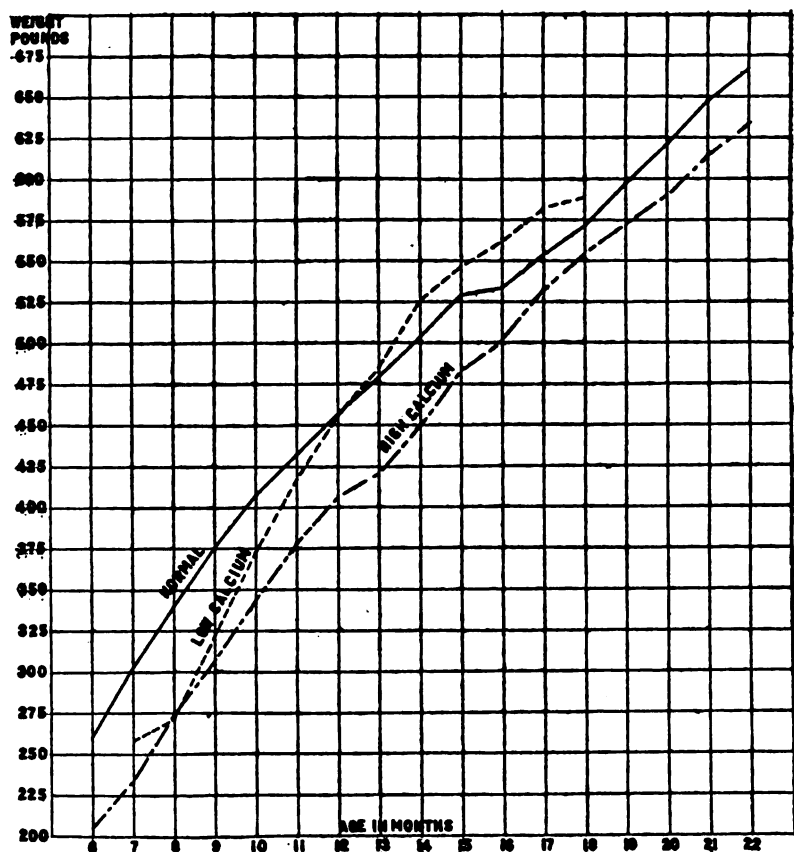


FIG. 15.—The calcium supply in relation to growth. The normal weight for Jerseys at this age is shown by the solid line. The line marked "low calcium" represents the weight of a Jersey receiving from 5 to 9 grams of calcium daily. This amount was so deficient that a general physical breakdown occurred at 18 months. The "high calcium" line represents the weight of a Jersey receiving from 20 to 29 grams of calcium daily. This animal remained in perfect health until taken off this experiment, which was more than a year after the breakdown of the other animal. The result with skeletal growth was almost identical with that of weight, indicating that the first effect of a "low calcium" supply in the ration manifests itself in a general physical breakdown and not by a retardation in the rate of growth. (Table 22)

An examination of the literature concerning the relation of the amount of calcium in the ration to growth reveals that similar observations have been made on other animals. Voit¹⁵ concluded from his

experiments that animals which received rations low in mineral matter, but otherwise normal and abundant, increase normally in weight; and the first result of low calcium feeding is an abnormal condition of the bones generally described as rickets. Aron and Sebauer¹⁶ compared the rate of gains made by dogs fed on a ration high in calcium with gains made by similar animals on a ration deficient in this mineral. The rate of gain was practically the same for both rations altho the deficiency in calcium was so great in the one that the bones of the animal which received it were badly affected. The symptoms were those of rickets. While the gains in weight by the animals on the low calcium ration were not affected, it was noticeable that the movements of the animals were hindered and that there was a tendency for a nervous breakdown and digestive disturbances.

While the data presented are too limited to justify any definite conclusions, it is doubtful under practical feeding conditions if the calcium supply will either limit or accelerate the rate of growth of dairy cattle, or prove to be a factor of importance in determining their size when mature.

RECOVERY FROM RETARDED GROWTH

The results obtained by the authors with dairy cattle bear out to a great extent the conclusions of Waters¹⁷ to the effect that there is clearly a strong tendency to compensate for adverse conditions which have retarded the growth of the animal and kept it below the normal. There are two ways in which recovery may take place; (1) by an increase in the rate of growth after the period of adversity is past; (2) by prolongation of the period of growth. When an animal, which has been retarded in growth because of an inferior ration, is given an ample ration, the tendency is strong to use a very large amount of food and to make a growth in excess of the normal rate, and in this manner again to approach the normal size for the breed and age represented. On the other hand, an animal which has made growth above the normal because of a very liberal ration shows a marked retardation when the conditions become less favorable. Conditions which may cause a growth above normal for a group of animals under low conditions of nutrition may cause a growth below normal for a group that is above normal as the result of a period of high nutrition. These results are shown clearly by data taken in connection with experiments on wintering dairy heifers.

One group of these heifers received a ration sufficient to bring about a daily gain of 1.65 pounds during a six months winter-

ing period. A second group was fed a ration which resulted in an average daily gain of 0.36 pounds. At the end of the six months wintering period both groups were placed on pasture. The results are given in Table 23 in the form of gain in weight and height at

TABLE 23.—COMPARISON OF WINTER AND SUMMER GAINS IN PER CENT OF THE NORMAL

	Group 1 Gain 1.65 lbs. daily in winter	Group 2 Gain .36 lbs. daily in winter
Winter 6 months		
Gain in weight	191	15
Gain in height	145	97
Summer, 6 months on pasture		
Gain in weight.....	43	102
Gain in height	85	119

withers in per cent of the normals. These data show a marked difference in gain by the two groups as compared with the normal. The group which received the liberal ration in winter gained less than the normal the following summer, while under the same pasturing conditions the group that made a gain far below the normal during the winter made a gain above normal both in weight and height.

The second method of recovery from a stunted condition is by a prolongation of the period of growth. The heavy-fed animal reaches a comparatively early maturity. The light-fed animal grows more slowly and for a longer period of time until a more advanced age has been reached. In some cases the light-fed animal may completely recover when placed on a more liberal ration. In a few cases such an animal has been known to reach a size even greater than that of an animal which has been given a good ration and has made a steady and liberal growth from birth. An example of such a case is shown for two individuals in Fig. 16. As would be expected, the figures for a large group are not so extreme or striking.

Table 24 shows the relative size of the heavy versus light-fed Holsteins and Jerseys and the difference in centimeters at each point. This shows that with both breeds there is a strong tendency for the heavy-fed animals to cease growing some time before cessation comes to the light-fed group. It is doubtful if on the average, the

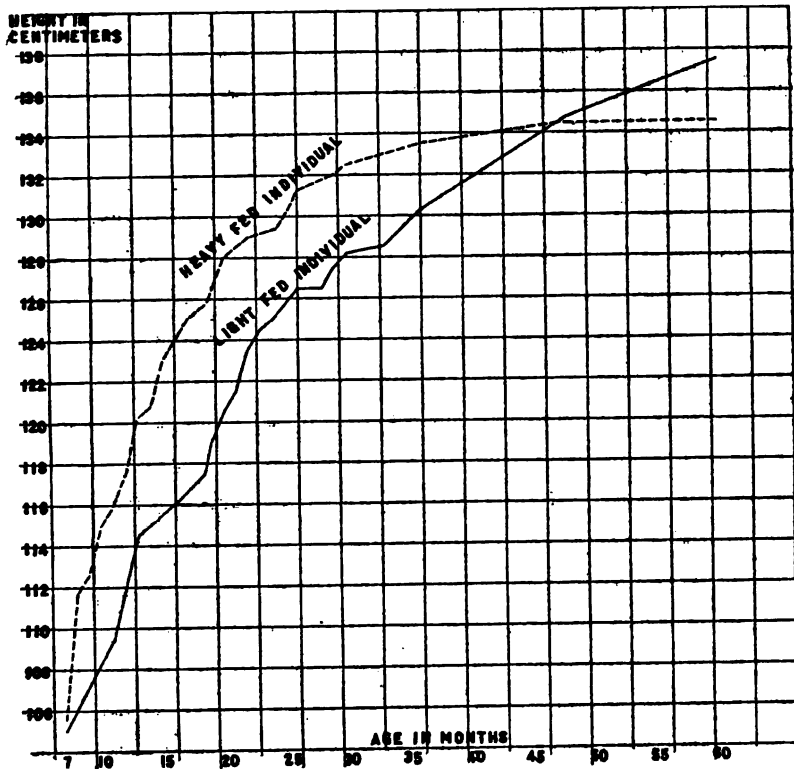


FIG. 16.—Recovery from poor nutrition thru prolongation of growth. Each line represent an animal. The two were practically the same height at 6 months of age. The heavy-fed animal made a more rapid growth and reached maturity quicker. With the light-fed animal the period of growth was greatly prolonged and she was taller at maturity than the heavy-fed animal. The growth of these two cows is typical of the results obtained with groups except that on the average the light-fed animals did not reach the size of the heavy-fed ones

light-fed animal will ever attain the size of the heavy-fed animal altho it has a strong tendency in that direction.

The same was observed by Waters¹⁸ who states that it is possible to recuperate by prolonging to some extent the period of growth but, "just to what extent this is possible we cannot yet form even an estimate, but results already obtained indicate quite clearly that an animal when sparsely fed thru the early part of its life may grow after the time when an animal that was normally nourished is matured and has ceased to grow."

TABLE 24.—RELATIVE SIZE OF HEAVY VS. LIGHT-FED HOLSTEINS AND JERSEYS AND DIFFERENCE IN CENTIMETERS AT EACH POINT

Age in months	Holsteins			Jerseys		
	Heavy-fed	Light-fed	Difference in centimeters	Heavy-fed	Light-fed	Difference in centimeters
1	76.7	75.6	1.1	70.1	71.6	-1.5
2	81.7	80.4	1.3	73.1	75.9	-2.8
3	88.1	84.6	3.5	77.9	80.5	-2.6
6	103.4	96.7	6.7	92.7	92.3	+ .4
9	111.5	101.2	10.3	102.2	97.2	5.0
12	117.8	106.3	11.5	108.8	102.5	6.3
18	125.4	115.3	10.1	116.6	110.6	6.0
24	130.1	121.6	8.5	121.8	116.3	5.5
36	133.7	126.9	6.8	125.1	121.9	3.2
48	134.9	129.5	5.4	125.7	123.0	2.7

CONCLUSIONS

Measuring growth.—It is concluded from the data presented that it is impossible to represent the growth of an animal by a single term. It appears necessary to use one unit to measure the growth of the skeleton and another for the gain in weight. The growth impulse is decidedly stronger in the skeleton than in the fleshy parts of the body. Environmental conditions of the growing animal have a much stronger effect upon the weight than upon the growth of skeleton. A difference in rations fed that resulted in a variation of 46 per cent in gain in weight between two groups resulted in a difference of only 7 per cent in the growth of the skeleton.

A study of monthly measurements taken on 16 dairy heifers from birth to maturity leads to the conclusion that any one of several skeletal measurements may be used as a measure of the growth of the skeleton. On account of the small limit of error, and the ease with which it is taken, the height at withers is selected as the measure of skeletal growth. The growth of the animals is measured by two units, (1) gain in live weight, (2) increase in height at withers.

Size of calf at birth.—Little, if any, relation can be found between the size of the calf at birth and the rate of growth or the size of the animal at maturity.

Breed as a factor in growth.—The rate of growth in skeleton by the Jersey and Holstein is practically the same from birth to 24 months but is greater by the Holsteins from this date on. The rate

of gain in weight from birth is somewhat greater by the Holsteins. There is a well marked breed characteristic with reference to the age at maturity. The Jersey reaches maturity in skeletal growth between 3 and 4 years, the Holstein between 4 and 5 years. The maximum weight is reached by both breeds about two years after the growth of skeleton ceases.

Liberality of the ration.—The amount of digestible nutrients consumed during the growing period has some effect upon the rate of growth of the skeleton, but the relation to the weight is much more pronounced. A ration supplying a large amount of readily digestible nutrients increases the rate of growth, especially in weight; hastens the time of maturity; and allows the animal to develop to the full limit of its inheritance. The animal which receives less nutrients in its ration during the growing period is thinner in flesh; and if the plane of nutrition is decidedly lower, the rate of skeletal growth is also slower, the growth period is somewhat prolonged; and the tendency is for the animal at maturity to be smaller than the one raised on a liberal ration.

Gestation.—Gestation has practically no effect upon the rate of growth of heifers. This is in keeping with previous investigations of this Experiment Station which indicate that developing the fetus exerts but a slight tax upon the animal.

Lactation.—The growth of a lactating animal is checked materially both in regard to the skeleton and the weight. Heifers in milk make decidedly less growth than animals of the same age and breed that are farrow or pregnant. The effect of early lactation is sufficient to check the growth of the animal to the extent that the size at maturity is somewhat influenced. Heifers which calve when 20 to 24 months old do not average so large at maturity as heifers that calve first when 28 to 34 months old.

Combination of early calving and light rations.—The most decided effect upon the size of dairy cows when mature results from a combination of light rations during the growing period and early calving. It is believed that next to hereditary factors which may determine the upward limit of growth, the combination of early calving and light rations during the growing period is the main cause for the numerous undersized cows in many commercial herds.

Relation of calcium in the ration to growth.—A Jersey heifer 6 months old was placed on a ration so low in calcium that a physical breakdown occurred at the end of 13 months. Her rate of growth was compared with that of a heifer which received a high calcium ration. The rate of growth by the two was practically the same and was equal to the normal up to the time of the breakdown of

the one which received the low calcium ration. This result is in accordance with investigations conducted with other animals which indicate that the rate of growth is not appreciably affected by the amount of calcium supplied, and that the first indications of a deficiency of this constituent is a physical breakdown.

Recovery from retarded growth.—There is a strong tendency for animals to recover from retarded growth if conditions are favorable later. This may be accomplished by a more rapid rate of growth or by prolonging the period of growth. If the retardation, especially in skeletal growth, has gone too far the animals will not, however, reach the normal size.

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UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
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Some Factors Favoring or Opposing Fruitfulness in Apples



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SOME FACTORS FAVORING OR OPPOSING FRUITFULNESS IN APPLES *

The Effect of Certain Conditions and Practices on the Development and Performance of the Individual Fruit Spur

C. C. WIGGANS

INTRODUCTION

It is a generally observed fact that certain varieties of apples tend to bear crops in alternate years, while others produce annual yields. Some varieties are light bearers but others yield heavy crops. In some cases the same variety, or even the same tree, shows great variation in its performance from year to year. The principles underlying these variations in behavior are of scientific interest as well as of great importance to practical fruit growers. Horticultural literature contains numerous references to the biennial crops of the Baldwin in the New England and New York fruit growing sections. Among the varieties grown in Missouri, the Ben Davis, Gano, Ingram, and York show marked alternation of crops, while the Jonathan, Winesap, Grimes, and Missouri generally may be depended upon to give satisfactory crops each year.

The investigator in considering the factors influencing fruitfulness in apples, must, first of all, give his attention to a study of the principles underlying fruit bud formation, for the flower must, of course, precede the fruit. Many and varied have been the opinions of investigators as to the factors causing flower production. The argument has sometimes been advanced that the blooming power is inherited, while some writers have maintained the view that flowers are dependent upon the presence of a certain specific "blossom building" substance. The latter view has been especially noticeable among German investigators. Environmental factors such as light, heat, accident, etc., have been considered the all important ones in some cases, while in others, the effects of certain cultural practices have been used as a basis for the explanation of the phenomenon. Seemingly, the problem has been of as much interest to plant physiologists and morphologists, as to the practical growers themselves.

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It has long been recognized by those interested in plant life that in every plant there are two seemingly antagonistic forces, one of which is striving to preserve the individual plant, and the other, to perpetuate the species. The first of these activities expresses itself in the formation of purely vegetative parts, such as stems, roots and leaves, thru which the life of the individual may be lengthened, while the latter has to do with the formation and maturation of seeds in greater or smaller numbers by which the species may be carried over from one generation to the next. The former may be spoken of as vegetative activity and the latter as reproductive activity, or, in the case of fruit trees, as wood growth and fruit growth.

Vegetative activity always precedes reproductive development and, so long as it proceeds with undiminished vigor, few or no blossoms will be formed. With our tree fruits the period of vegetative activity may be several years in length while with certain annual plants it may be a matter of only a few weeks. In any case, however, the maximum vegetative period passes before heavy reproduction begins. Maintaining the vigor of the wood growth serves very materially to delay the formation of fruits, while, on the other hand, a heavy fruit crop tends to decrease greatly the vegetative growth. From these general observations, the obvious conclusion has been reached that it is impossible to have the greatest efficiency in both wood and fruit growth simultaneously in a single individual. A plant, then, cannot be of the highest degree of service to itself and to its species at one and the same time.

Apple trees during the first few years of their life produce few or no blossoms. The energies of the plant are directed to the formation of a framework of branches upon which the later crops of fruit are to be borne. Finally, however, the bearing age is reached but this is found to differ very materially in the different varieties and even in the same variety when grown under different cultural and soil conditions. From this time until its death, the tree remains a potential fruit bearing organization. The amount of fruit borne, however, often shows a very striking variation, ranging from a very light crop to a very heavy one. This phenomenon is sometimes spoken of as alternation.

Alternation, referring primarily to the bearing of heavy and light crops in alternate seasons, seems to be more or less a varietal characteristic. With certain varieties regular crops are expected, while with others a heavy crop is almost invariably followed by a light one. This habit of alternation also seems to be much more

characteristic of our later commercial varieties than of some of the older sorts grown in the orchards of the early settlers. This may have come about because of the emphasis that is now placed upon high yields. In the earlier days, when markets were limited, regular crops were more desirable than heavy crops.

In an investigation of the factors influencing fruitfulness in apples, so many avenues of research are open that it is folly to attempt to take all of them into consideration in a single investigation which must be more or less limited to certain lines. Previously, nearly all investigators have been inclined to consider the problem from the standpoint of the entire tree, or, of the entire orchard, in its relation to a specific treatment or factor. In this study, however, the main idea centers around the factors and conditions influencing the behavior of an individual fruit spur. Since the tree is composed of numerous individual fruiting parts, the factors influencing the individual spur must ultimately have a proportionate influence upon the entire organization. Hence an attempt has been made to keep constantly in mind the fruiting parts as individuals rather than in mass, and the greater part of the work has been done with the individual fruit spurs.

Moreover, for the purpose of this study, it is generally assumed that a blossoming spur is also a fruiting spur. Under field conditions, however, some flower clusters may fail to set fruit, but the fact still remains that a spur developing a blossom is a potential fruiting spur for the following year, and it is here so considered.

LITERATURE

A critical review of the literature bearing upon the factors favoring or opposing fruitfulness in apples reveals the fact that many explanations have been offered for the variations found in the fruiting habit of an apple tree. It is quite noticeable that many of these explanations are based upon general observations and conclusions rather than upon actual scientific data, and especially is this true in the older writings. Definitely planned experimental work is virtually confined to the last twenty-five years, and dates approximately from the time the agricultural experiment stations became well established in research work.

Not all writers have been interested directly in the production of an increased number of blossoms for some have been concerned with the reserve materials which are always found to be present in woody plants. The amount and nature of these reserves vary accord-

ing to the season and character of the part under consideration, and these variations have sometimes been used as a basis to explain the phenomena observed. Thus, are recorded not only the observations of horticulturists but those of biologists and chemists as well.

The natural evolutionary development of the apple during the centuries that it has been under cultivation, has very likely had considerable influence upon the cultural practices of the succeeding periods. Therefore, it seems but natural to suppose that the management suitable for the apple as it was first known would be not at all applicable to the modern commercial high yielding varieties. Also, an increasing knowledge of plant structure and function, in all probability, has been productive of improved methods of fruit growing. All recommendations, however, based upon either general observations or actual knowledge, have for their purpose an increase in the yield or an improvement in the character of the fruits borne.

One point upon which the majority of writers are in perfect accord is, that fruit bud formation is dependent upon a supply of reserve food material. With the better understanding of the sap flow in plants, this idea has become more and more prominent. Even the early writers seemed to appreciate that there is some connection between the food supply and the sap, and hence they devised methods by which they thought they could modify the sap and thereby also influence the food supply. Particular methods were evolved for the various parts of the plant and changes in the character of the food supply, etc., were also suggested.

Since many of the writers have considered the effects of several methods or treatments upon fruitfulness, it seemed advisable to consider the literature in chronological order rather than by topics. This plan has been used in the following review:

One of the earliest records found of an interest being taken in the factors influencing fruitfulness is the statement of Lonicerus (1587) quoted by Zacharias^{152*}. This early writer seems to have reached the conclusion that an excess of nourishment leads to a very marked extension of the vegetative branches, but that no fruit will be borne under these conditions. This same doctrine, that great vegetative growth is not compatible with great reproductive activity, can be subscribed to today.

According to Noehden¹⁰⁴, Van Oosten, (1711) the Dutch botanist, stated that a "moderate sap flow," secured by frequent transplanting or by summer pruning, will result in fruit production. While

*See bibliography for this and subsequent number references thruout.

he probably possessed very little knowledge concerning the sap flow, yet this writer suggested two methods which will encourage fruitfulness and these methods are even now sometimes used for this purpose.

The beneficial effects of ringing were observed by De la Baisse (1753), Bonnet (1754) and Duhamel (1758). These reports were recorded by Mobius⁹⁹. Duhamel apparently seems also to have had some knowledge of the effects of pruning.

Knight⁷⁸ early in the nineteenth century published many papers dealing with horticultural subjects. Among his observations, Knight made note of the increased fruitfulness of horizontal branches as compared with upright ones. He explained this by the assumption that the decreased sap movement in the horizontal branches was the direct cause of their greater fruitfulness. He suspected that the heavy fruit crops borne immediately following a warm bright season when only a few fruits were matured, was due to the fact that the sap had not been expended in maturing an excessive crop. In some of his earlier papers he leaned to the belief that the bearing age of a tree is dependent to a large extent upon hereditary factors, but later, ringing is mentioned as a way of increasing fruitfulness, this being due to the accumulation of descending sap. Knight really had a much better knowledge of plant physiology than his predecessors and hence was enabled to give a more nearly correct interpretation of his results. It is interesting to note the close agreement between some of his ideas and those of the present day.

Forsyth⁴⁶ in a textbook on the general subject of fruit growing published in 1802 made the following statement, "Never shorten the young branches except they are very thin. . . . nor prune any of the young shoots the second year, as many of the eyes, almost at the end of the shoot, will, if it be strong, become fruit buds next year." Evidently, this writer had been making some very accurate observations upon the method of fruit spur formation.

That fruit bud formation may be stimulated by checking or diminishing the growth was the opinion of Noehden¹⁰⁴ (1818). Ringing was suggested as one means of accomplishing this end.

Prince¹¹⁸ (1830) believed that the amount of available moisture had a marked effect upon the fruitfulness of grapes.

Philips¹¹² (1831) declared that, "Pruning is to be avoided as much as possible as it creates useless branches and prevents the fruiting." Cole²⁸ (1849) mentioned the following factors as being conducive to fruitfulness and early bearing; root pruning, ringing,

bending down the branches, transplanting, use of certain stocks, shortening-in, and change of soil or climate. He stated also that certain varieties are regular bearers while others bear only in alternate years. However, he did not agree with the opinions expressed by others that this alternation is due to exhaustion and points out, in support of his contention, that certain kinds produce annual crops. In his opinion, the bearing year in alternating varieties may be changed by removing all of the blossoms during the heavy bearing year.

Barry¹⁸ (1851), after observing that fruit buds originate as leaf buds, the differentiation taking place during the latter part of the growing season, finally stated that the immediate causes of fruit bud formation are not satisfactorily understood. He quoted Dubreuil, however, as being of the opinion that fruit buds are dependent upon stored plant food and that their formation is brought about if the circulation of sap is obstructed. This obstruction causes a slowing up of the sap movement so that the sap is more thoroly elaborated, and hence, becomes better adapted to fruit bud formation. Lindley²² (1852) believed that plants must attain a certain age before flowers will be formed, and that this age may be influenced materially by the nutrition of the tree. He further stated that fruit bud formation is probably due to an accumulation of plant food.

Field⁴¹ (1859) recommended breaking, pinching, and twisting the branches as methods of inducing fruitfulness in the pear. He believed also that a large quantity of fibrous roots is essential for fruit production and hence root pruning may be practiced. Downing³⁶ (1864) agreed with Field that root pruning may be useful but he assigned an entirely different reason for it. By lessening the root system an overabundance of plant food is made available for the branches and this material then forms fruit buds. In the opinion of this writer, heavy crops exhaust the tree and thus cause alternation. However, this habit may be overcome by thinning while the apples are small. He also recommended that the soil be kept in "high condition."

Rivers¹²¹ (1866) was a very strong advocate of root pruning, especially for dwarf trees, as a remedy for barrenness. He supposed that trees could be kept fruitful only by preventing the formation of large roots since these go downward and imbibe crude sap which causes great twig growth and few or no fruits.

Warder¹⁴³ (1867) summed up his observations by stating that fruit bud formation is due to the accumulation within the tree of nutritive materials, and the exhaustion of the soil of wood-forming

elements. From the time the tree reaches maturity, then, the bearing habit is regulated by the balance between the materials which produce wood and those that produce fruit. Young trees need summer pruning to check their vigor and cause laterals to develop while older trees require dormant pruning to thin the fruit and to renew the vigor. Thus, it is seen that in the young trees, vegetative vigor must be restrained and fruit production encouraged, while in the aged trees, the exact opposite is the case.

For twenty-five years following the publication of Warder's "American Pomology" very few papers appeared dealing with the fruitfulness of apples. Seemingly, the writers of this period were content to let the question stand without additional comment. However, about 1880 there began to appear frequent articles concerning the chemical nature of the stored plant reserves. Halsted⁶¹ (1890) pointed out the importance of reserves to trees and also made some descriptions of the various storage tissues. He found but little apparent difference between leaf buds and fruit buds so far as sugar storage was concerned. However, he pointed out that leaf buds store up much more starch than the others on account of the fruit buds having to supply the developing fruit with this material. In his opinion flower buds are not terminal but rather simply overshadow the terminal leaf bud which is down among the blossoms. Fischer⁴⁸ (1891) also called attention to the importance of reserves, and of their activities before any exterior growth takes place.

Maynard⁹⁷ (1888) concluded from some girdling experiments with crabapple trees that girdling will cause the production of an abnormal number of blossom buds but that it is an unsafe stimulus to use. Taft¹³⁵ (1891) gave root pruning as one cause of fruitfulness, but stated that this practice is not to be recommended. Quinn¹¹⁹ (1892) said that summer pruning causes a change in the flow of sap from the ends of the branches which results in fruit formation. Gurney⁶⁰ (1894) assigned exhaustion as a cause of alternation but said, "Bearing only in alternate years can in a large measure be broken up by a careful system of feeding or fertilizing."

Sorauer¹³⁰ (1895) has given this problem considerable attention, mainly from the physiological point of view. He maintained that under certain conditions, controllable to some extent by man, buds may be changed from one form to another. He said in part:

"Plants will only develop flowering buds when the food material formed in the leaves is copiously stored up in the stem and branches as reserve material, and not when this material is immediately used up in the production of new vegetative organs.

"Of our apple trees it is a well known fact that in warm insular climates they grow into magnificent foliage trees but remain unproductive of fruit.

"That a diminution of the supply of water accompanies the production of flowers in nature may be gathered from the fact that most trees and shrubs produce their flowers on short reduced branches or spurs. The comparison of the anatomical structure of such a short shoot with that of a long leafy shoot confirms our statement, too, that an increase in stored food material is necessary for the production of flowers. The former shoots have by far more storage tissue than the latter.....

"The withholding of water in such a treatment prevents the use of assimilated plant substance for the growth of new shoots and causes it to be stored up near the buds.

"For the production of flowering buds it is essential to decrease the supply of water and of nitrogenous salts, to increase the phosphates supplied to the plants and to increase the illumination."

Sorauer also discussed to some extent the effects of pruning upon fruitfulness and suggested that bending, twisting, notching, ringing, and peeling may be used to make pruning even more effective.

Klebs⁷⁶ (1890-1905) published several papers upon subjects relating to the reproduction of plants. His earlier investigations were carried out with algae and fungi because of their simplicity and rapidity of development, and also because the external conditions could be so easily and at the same time absolutely controlled. From the lower forms, however, he progressed to the use of the higher species and his later experiments were with phanerogams. This writer, in particular, emphasized the fact that the environment of a plant plays a most important role in the rate and kind of development made by it and its various parts. He showed that a plant may remain vegetative indefinitely if placed under the proper conditions. On the other hand, when the vegetative growth is inhibited reproduction at once begins. These changes in the character of the growth may be brought about entirely by a change in external conditions.

Work with the lower plants convinced Klebs that reproduction is affected by the amount and intensity of light, heat, moisture, and food supply, while the later experiments led him to believe that higher plants reacted in precisely the same way. Plants pass from the vegetative to the flowering state with changes in their external conditions and, at the same time, interior changes resulting in greater storage of plant food may also be taking place. Flowers, however, are not the result of an absolute amount of nourishment but rather of the relation between the decomposition and recomposition of these substances. In support of this opinion, he pointed out the fact that

badly nourished plants always blossom early. Intense light and low humidity are favorable to flower production and the intensity of nutrition also has great significance in this connection. Lessening the food supply results in flower production, provided the plant possesses reserves. This is the condition brought about by ringing. Whether external conditions are to exert a favorable or unfavorable influence upon reproduction depends altogether upon the effect which they have upon internal conditions.

Other investigators coming after Klebs and Sorauer have submitted additional proof that there is a definite relation between the food supply and the character of plant development. External conditions favoring flower growth always oppose extensive twig and leaf development. External conditions favoring great availability of plant food always result in vigorous vegetative growth. Climatic conditions may have quite an influence in this respect. This was very forcibly brought out by Balmer¹⁰ (1896) in describing the difference in the fruiting habits of the same variety when planted under different conditions. In a region where rainfall is abundant, excessive vegetative growth is noticed, while in a section where the rainfall is much less, even the young trees tend to overbear. This, of course, means that much more attention must be given to pruning and other orchard operations under those conditions.

During the more recent years a considerable literature has been developed in connection with the effects of such orchard operations as pruning, fertilization, cultivation, spraying, ringing, etc., and along with this, some general observations with regard to the fruiting habit.

Schweitzer¹²⁷ (1898) commenting upon the results secured from the ash analysis of twigs from apple trees said, "surely the much larger absolute amount of lime, phosphoric acid and potash in the bearing twigs must be either the cause or the condition of their bearing."

Bailey⁷ (1898) enumerated several factors that may cause barrenness in apple trees but finally stated that in the nature of the tree there is no reason why it should not fruit more or less continuously. Later⁸ (1911) this same author concluded that the side bud on a bearing spur does not receive sufficient nourishment to develop into a fruit bud and, even tho the blossoms may be removed, it still may not produce a fruit bud for the following year. Waldron¹⁴³ (1899) mentioned an "inherited tendency" to produce flower shoots as being a very potent cause of fruitfulness.

Goff^{51 52 53} (1899-1901) in making studies of blossom formation in our common tree fruits showed that environmental factors have

great influence upon the early development of the bud. He concluded that fruit buds are due to nutrition rather than structure since a spur may bloom at one, two, or three years of age, or it may never bloom, and also because of the fact that a spur may bloom and even fruit two years in succession. Alternation is not due to exhaustion since a weakened or exhausted tree always produces a large number of blossoms. Very favorable conditions for fruit bud formation result in such great development of these buds during that season that no spurs remain for the development of buds for the succeeding crop. He⁵⁵ also said (1916) "a water supply insufficient for rapid growth may suffice for abundant fruit bud formation," and then called attention to the fact that fruit buds are usually formed during the drier part of the year.

Daniel³² (1900) declared that from the physiological standpoint there is little or no difference in the effects of girdling and grafting.

Experimental evidence submitted by Brown and Escombe³⁰ (1902) indicates that the amount of carbon dioxide in the air has a very marked effect upon flower formation.

Thomas¹³⁷ (1902) called attention to the fact that some varieties fruit more abundantly on the younger wood than do other sorts. He also stated that summer pruning hastens the formation of fruit spurs near the base of the pruned twig much more than dormant pruning.

Speaking with reference to thinning, Beach¹⁶ (1903) said, "thinning the fruit does not appear to cause any material change in either the amount or regularity of the fruit production."

Sablon¹²³ (1903) reported that the reserves in the twigs of a pear grafted upon a quince root are greater than those of a tree growing upon its own roots, thus tending to make it more fruitful. Later¹²⁵ (1906) he made further studies upon the reserves of trees and found that the great variation in the kind and amount of these reserves was dependent upon the season and the part under consideration.

Loew⁸⁵ (1905) combated the idea of earlier German writers that there is a specific blossom building material when he stated that blossoms are the result of a certain concentration of sugars. Fischer⁴⁴ (1905) agreed with Loew that there is no special blossom forming substance. He also stated that girdling, instead of causing starvation of the parts above the girdle, results in an accumulation of plant reserves thereby causing greater blossom production.

Flowers and flower bud formation require a relatively high illumination according to Clark²⁷ (1905), a fact which is supported by Paddock's¹⁰⁸ (1905) account of the greater and earlier fruitfulness of trees in the increased sunshine of high altitudes.

Chandler²⁴ (1905) presented the idea that alternation is due more to the formation of the blossom than to the later development of the fruit and for this reason thinning is not effective in overcoming the alternating habit. He also stated that the bearing habit can be controlled by pruning only in case the pruning dates from the early development of the tree. Herrick⁸⁷ (1910) reached the conclusion that systematic thinning should have some influence toward annual cropping, thereby doing away with the "off years" of certain varieties.

According to Ikeda⁷¹ (1910) the Japanese fruit growers have always felt that alternation is due to nature and can not be controlled in any way. He then told of the pruning which is done by breaking off the bearing twigs at the time the fruit is harvested.

Waugh¹⁴⁴ (1910) reached the conclusion that if a tree is starved, it will make no new growth, the spurs will deteriorate, and the crops become scant, while too much wood growth will take place at the expense of the spurs and fruit.

Manaresi and Tonegutti^{98 95} (1910) found that fruit-bearing wood is much richer in nutrients than foliage-bearing parts, and also that there are material differences in the size and shape of the leaves on the bearing and non-bearing spurs.

Although Newell¹⁰² (1910) stated that a single bud naturally cannot produce two crops in succession, yet, according to this author, the tree can be kept bearing annually. He expressed the opinion that the fruit bud receives no sap until the needs of the end of the branch have been fully satisfied.

Stewart¹³² (1910) said, "the off year may be frequently largely overcome by fertilization and other care," and later¹³³ (1917), recommended for maintaining high and uniform yields, first, the prevention of large crops by thinning, second, an ample supply of food and moisture, and third, the avoidance of injury to the roots thru cultivation, etc.

Pickett¹²⁸ (1911) reported that while fertilization had little or no effect upon the number of fruit buds, cultivation with or without a cover crop always showed an increase. A proper balance, easily destroyed by too much pruning, or other treatment, between the working area of the foliage and the food supply, is necessary to

insure a full and regular supply of fruit buds in apple orchard¹¹⁴ (1913).

Paddock and Whipple¹¹⁰ (1911) observed that varieties which frequently form fruit buds upon the one year wood are more likely to be annual bearers than varieties which fruit only on the older parts. The alternation of individual spurs is, in their estimation, due to a depletion of their energies by the fruit during the bearing year.

Dry weather at the time of fruit bud formation always makes a good prospect for the next year's crop, according to Macoun⁸⁸ (1912).

Batchelor¹⁴ (1913) thought that the spur needs a year to recover its exhausted energies after fruiting, and hence, a light crop is borne in alternate years. Newsham¹⁰³ (1913) agreed with this statement and then added that removing the blossoms or young fruit tends to cause annual crops. This writer also stated that checking the growth, while inducing fruitfulness, does not maintain it.

Magnien⁹² (1913) recommended basic slag as a fertilizer for apples because it leads to abundant fruit bud production. According to Remy¹²⁰ (1913), blossom formation is not affected by high amounts of phosphorus, potash, or lime, but a certain amount of nitrogen seems to be necessary.

Howe⁶⁹ (1914) said that ringing, while sometimes effective in inducing or increasing fruitfulness, is an unsafe stimulus to apply to fruit trees.

Gourley⁵⁷ (1914) reported that practically all methods of tillage treatment resulted in yields superior to those secured from the sod plots. In making a detailed study of the fruit spurs, this author⁵⁸ (1915) found that the spur having a fruit bud upon it possessed a greater supply of starch than one without a fruit bud. The leaf area of a spur is always greater during the non-bearing year. Thinning experiments with the Baldwin did not give appreciable results so far as the regular bearing of the tree was concerned.

Sears¹²⁸ (1914) agreed with Thomas¹²⁸ (1914) that rank growth is always opposed to fruitfulness since an abundance of plant food is essential to blossom formation. He further stated that the effect of summer pruning is not well understood—it depends upon the time, nature, and extent of the treatment,—but Drinkard⁸⁸ (1915) and Batchelor and Goodspeed¹⁵ (1915) recommended summer pruning as a means of stimulating fruitfulness.

Alderman and Auchter³⁴ (1916-17) in a series of experiments in West Virginia came to the general conclusion that heavy dormant pruning on young trees delays the bearing age while lighter pruning

hastens it. In the case of old trees, however, vigorous pruning stimulates fruit production. They found that corrective dormant pruning was more effective in stimulating fruitfulness than summer pruning. Auchter⁸ (1917) states "thinning does not influence subsequent crops nor cause trees naturally biennial in bearing habit to bear each year."

From the work of Lewis⁸¹ (1915), Gardner⁴⁷ (1915), Kraus⁷⁹ (1915), Magness^{89 91} (1916), Bradford¹⁸ (1915), and Yeager¹⁵¹ (1916) of the Oregon agricultural experiment station, the following general conclusions may be drawn: A large percentage of the spurs bear only once in two years. Varieties fruiting on the newer parts are more regular bearers than those which fruit on the older portions. The condition of the tree as a whole determines whether a spur will fruit two years in succession. There is a correlation between the size of a spur and its productiveness but the floriferousness of a spur lessens as the spur becomes older. Fruit bud formation is due to a fair amount of adjacent leaf surface since the plant foods are stored up near the point of synthesis, a state of affairs making each twig more or less independent of the remainder of the tree. The greatest effects of pruning are manifested near the pruning cut. Summer pruning stimulates fruit bud formation near the base of the pruned twig only, and not thruout the body of the tree where the fruit spurs have already become well established.

Winkler¹⁴⁸ (1916) concluded that under conditions favorable to enzyme action, vegetative growth predominates, while conditions inhibiting enzyme activity are favorable to reproductive activity. An accumulation of carbohydrates is given as one condition bringing about the cessation of enzyme action.

According to Pickering¹¹⁵ (1916) it is *unproven* that fruiting is due to a gradual accumulation of the plant reserves which become exhausted thru the production of a heavy crop. He concludes that the great variation found in the size of crops borne over a series of years is due to atmospheric conditions more than to any other factor even tho there is a tendency to alternation in certain varieties.

Retardation of growth always results in an increase in the starch proportion of the parts above ground,—at least, these are the results reported by Hartwell⁶⁴ (1916) after working with the potato.

Barker and Lees¹² (1916) reported that different degrees of dormant pruning result in practically an equal number of fruit buds being formed but that these buds are differently distributed on the tree.

Heinicke⁶⁶ (1917) stated that a dry sunny season is favorable for fruit bud production. He also found that bearing spurs are

always heavier in weight than non-bearing spurs and that the greatest leaf area is found on the spurs with the greatest amount of connecting tissue. The age of the spur from two to four or five years apparently has little effect on its fruitfulness.

The established habit of the tree is far more influential upon the fruitfulness than the kind or extent of the pruning, according to Kains⁷³ (1917). Twig and small branch pruning, however, tend both to thin the fruit and favor regular annual bearing.

Butler²² (1917) said that the theory that alternation is due to exhaustion has little or no foundation, but that it is a natural phenomenon to be predicated from the mode of flowering. Flower bud development, no matter on what kind of a branch, always occurs where six to eight sessile leaves have developed in a single period of vegetation. A slow, quick maturing, sessile growth, due to a scant but sufficient moisture supply, coupled with a vigorous photosynthetic activity is responsible for flower bud development. In his opinion small yearly departures from the mean growth will result in a more uniform production.

GENERAL STATEMENT OF THE PROBLEM

The apple yield of the entire United States shows a wide variation from year to year as the following table will indicate.

TABLE 1.—ANNUAL PRODUCTION OF APPLES IN U. S.*

Year	Yield Barrels	Year	Yield Barrels
1909	48,707,000	1913	48,470,000
1910	47,213,000	1914	84,400,000
1911	71,340,000	1915	76,670,000
1912	78,407,000	1916	67,415,000

*Yearbook, U. S. D. A., 1916, p. 635.

The foregoing variation is probably to be expected when it is considered that allowances must be made for the wide ranges of both soil and climate over which the apple is grown in this country, and also because of the increased plantings. Unfavorable conditions in any one section are likely to be balanced by favorable ones in another, and so, on the whole, the foregoing figures do not represent the actual variation in yield which may be expected in any particular section.

When the Missouri yield alone is considered even a greater variation than that shown in Table 1 is found. This smaller area represents more nearly uniform conditions and hence indicates the degree of difference which is often found in apple yields.

TABLE 2.—ANNUAL PRODUCTION OF APPLES IN MISSOURI*

Year	Yield Barrels	Year	Yield Barrels
1889	2,899,000	1903	2,067,000
1890	2,420,000	1904	3,233,000
1891	3,220,000	1905	2,150,000
1892	1,381,000	1906	6,567,000
1893	936,000	1907	433,000
1894	2,569,000	1908	2,533,000
1895	4,816,000	1909	3,323,000
1896	3,780,000	1910	2,533,000
1897	3,599,000	1911	3,867,000
1898	784,000	1912	6,400,000
1899	2,165,000	1913	2,533,000
1900	2,767,000	1914	4,157,000
1901	3,500,000	1915	6,287,000
1902	3,900,000	1916	2,700,000**

*Missouri Bureau of Labor Statistics Report 37, 1915, p. 286.

**Yearbook U. S. D. A. 1916, p. 635.

An examination of the foregoing table reveals the interesting fact that, as a rule, the heavy yield occurred every third year. For instance, the years 1915, 1912, 1909, and 1906, all showing heavy yields, are invariably followed by a relatively light crop which in turn is followed by a medium yield which, apparently, leads up to the heavy production again. The same is shown to some extent for the earlier years also, but here such regularity can hardly be expected since during the period 1889 to 1899 very extensive plantings were being made and each year in that period showed a correspondingly greater number of trees in bearing. Such a state of affairs would naturally interfere with the regular sequence of bearing. However, the yields for the later years, which probably are more accurate than the others, represent the production of a more uniform number of trees and consequently may be considered as more representative of the way in which trees normally bear.

From the foregoing it is evident that the question of fruitfulness in apples is a very important one to the fruit grower who demands regular annual crops in order that his business may be a stable one.

A search of the literature previous to the initiation of this project revealed the fact that no particular attention had ever been

given to a study of the individual fruit spurs. Previous investigators have based their opinions with respect to spur behavior, largely upon general observations and conclusions. Casual observations made by fruit growers generally have indicated that there is probably a correlation between the previous performance of a spur and its later fruitfulness, but data either confirming or contradicting this view have not been recorded.

In the light of the above facts, when this investigation was begun in 1913, it seemed advisable to center the attention upon the individual fruiting branches rather than to consider the performance of the tree or orchard as a whole. It seemed only logical to look in this direction for an answer to the question, Is the alternation of a Gano tree due to the inability of the individual spur to blossom and fruit two years in succession, or to some other factor, or factors? The question also arises as to whether the regular bearing of the Jonathan is caused by the fact that only a relatively small proportion of the spurs blossom any one season. Here again an answer must be sought by examining the fruit spurs and not by casual observation of the entire tree.

While the general object of this investigation has been to determine the effect of certain conditions and practices upon the development and performance of the individual fruit spur or branch, the following specific objects may be mentioned:

1. To determine whether an individual spur or branch blossoms two or more years in succession, in alternate years, or only once in its life history as a fruiting part.
2. To determine whether there is a correlation between the concentration of plant sap and stored reserves in bearing and non-bearing parts, and the observed bearing or non-bearing condition.
3. To correlate the leaf area of a spur with the fruiting habit that it possesses.
4. To observe the exact effect of girdling upon the concentration of sap in various parts of the trees.
5. To determine the effect of fertilizers upon dwarf trees planted in pots.
6. To record the osmotic strength of sap from different parts of trees grown under different systems of tillage.
7. To note the effect of certain systems of pruning upon the formation and development of the fruiting parts.
8. To note the effect of etherization upon the fruiting parts of young trees.

SPUR PERFORMANCE RECORDS

In order to determine accurately the exact behavior of the individual spurs, it is essential to keep performance records of the spurs over a series of years. Accordingly, in the fall of 1913 a suitable label was attached to each spur that had produced a fruit that year. (Fig. 1.) This labeling was carried out systematically upon one tree each of the Jonathan, Gano and Rome varieties. These trees were located on the Horticultural Grounds of the Missouri Experiment Station. They were approximately eighteen years old and apparently in full health and vigor.

In the spring of 1914, labels were attached to all of the blossoming spurs on the same trees, these labels being so marked that they could be distinguished from those attached the previous season. At the end of the season still another distinguishing mark was made upon the labels attached to the fruiting spurs. These marks were so made that by an examination of the label it was possible to determine the exact behavior of that spur during the past year. The results of the first year's observations are:

Variety	Gano	Rome	Jonathan
Number of spurs fruiting in 1913.....	598	223	228
Number of same spurs blooming in 1914..	49	19	36
Percentage	8.2	8.5	15.8

These data show distinctly that only a very small percentage of the spurs which fruit one season will even blossom the next year. However, there is shown a considerable difference in the behavior of the spurs upon the different varieties. Thus, it will be seen in the case of the Jonathan, the ability to blossom in the season immediately following the one in which a fruit is matured, is shown in nearly twice as great a proportion as in either the Rome or Gano. (The greater number of fruits on the Gano tree was probably due, at least to some degree, to the fact that it was a larger tree than either of the others.)

From these observations as a starting point the work was continued during the seasons of 1915, 1916, and 1917, so that in all this report covers a period of five years' work. Labels were attached to blossoming and fruiting spurs during these seasons so that at the end of the period it was possible to tell exactly how each spur had behaved each season since the observations were begun. The variety list was also extended so as to include Winesap, Grimes, and York, thus giving three varieties which are more or less regular

bearers and three that exhibit alternation under ordinary conditions. Some later observations were also made upon fourteen-year-old trees of various varieties growing in the famous loess soil along the Missouri River.

Obviously, it would be almost impossible to record the performance of every spur upon every tree under observation. Hence, in the following figures no attempt has been made to include all of them. In each case, however, the number taken has been large enough to preclude accidental variation, and since they were taken from various parts of the tree so as to include all the different conditions found on the tree, they may be taken as being representative of the tree as a whole.

In Tables 3 to 13 inclusive, an attempt has been made to systematize the blossoming records secured on the above trees. These tables represent really the summary of still longer tables, and in order to simplify them, no account has been taken of the spurs which both blossom and fruit in distinction to those which blossom only. Since only a limited number of combinations are possible for each spur's performance during the five-year period, the spurs showing the same sequence of blooming and non-blooming have been grouped together. New spurs are, of course, being added to the tree each year, so it must be remembered that the following records represent the behavior of the present spur system of the tree and not the system that was on the tree five years ago when the investigation began. Many of the spurs which were fruiting at that time have now developed into larger branches upon which other fruit spurs are borne.

In the tables, the first five columns contain a record of the behavior of the spur during the past five years, while the right-hand column indicates the number of spurs exhibiting that particular combination. The letter "B" represents in each case a blossom cluster for that particular season, while a blank indicates that no blooms were shown. It might be noted that the record for the year 1913 indicates, in the main, only those spurs which fruited that season altho an attempt was made to include all of those that blossomed. However, since it was sometimes quite difficult to be sure upon this point this explanation is given. The last line in each table represents the percentage of blossom, out of the total number, which blossomed in the given years.

TABLE 3.—PERFORMANCE RECORD OF INDIVIDUAL SPURS FROM A JONATHAN TREE GROWN IN CLAY LOAM SOIL

1913	1914	1915	1916	1917	No. of Spurs
---	---	---	---	B	333
---	---	---	B	B	86
---	---	B	B	B	41
---	B	B	B	B	3
---	B	---	B	B	59
B	---	---	B	B	2
---	---	B	---	B	238
---	B	B	---	B	21
B	B	B	---	B	2
B	---	B	---	B	97
---	B	---	---	B	66
B	B	---	---	B	1
B	---	---	---	B	3
---	---	---	B	---	137
---	---	B	B	---	47
---	B	B	B	---	11
B	---	B	B	---	5
---	B	---	B	---	101
B	---	---	B	---	2
---	---	B	---	---	61
---	B	B	---	---	5
B	---	B	---	---	9
---	B	---	---	---	15
B	---	---	---	---	1
9.0%	21.1%	40.1%	37.3%	70.7%	1346

TABLE 4.—PERFORMANCE RECORD OF INDIVIDUAL SPURS FROM A JONATHAN TREE GROWN IN LOESS SOIL

1913	1914	1915	1916	1917	No. of Spurs
---	---	---	---	B	134
---	---	---	B	B	92
---	---	B	B	B	20
---	B	B	B	B	1
B	B	B	B	B	1
B	---	B	B	B	3
---	B	---	B	B	12
B	---	---	B	B	2
---	---	B	---	B	51
B	---	B	---	B	9
---	B	---	---	B	2
---	---	---	B	---	155
---	---	B	B	---	10
---	B	B	B	---	1
B	---	B	B	---	1
---	B	---	B	---	44
B	B	---	B	---	1
---	---	B	---	---	15
B	---	B	---	---	2
---	B	---	---	---	1
3.4%	11.0%	20.4%	61.6%	58.7%	557

TABLE 5.—PERFORMANCE RECORD OF INDIVIDUAL SPURS FROM A GRIMES TREE GROWN IN CLAY LOAM SOIL

1913	1914	1915	1916	1917	No. of Spurs
---	---	---	---	B	250
---	---	---	B	B	21
---	---	B	B	B	9
---	B	B	B	B	1
---	B	---	B	B	5
---	---	B	---	B	185
B	---	B	---	B	42
---	B	---	---	B	2
B	B	---	---	B	2
B	---	---	---	B	2
---	---	---	B	---	110
---	---	B	B	---	17
---	B	B	B	---	1
---	B	---	B	---	12
---	---	B	---	---	197
---	B	B	---	---	12
B	---	B	---	---	25
---	B	---	---	---	3
B	---	---	---	---	5
8.3%	4.4%	42.7%	17.2%	57.0%	901

TABLE 6.—PERFORMANCE RECORDS OF INDIVIDUAL SPURS FROM A WINESAP TREE IN CLAY LOAM SOIL

1913	1914	1915	1916	1917	No. of Spurs
---	---	---	---	B	188
---	---	---	B	B	110
---	---	B	B	B	70
---	B	B	B	B	9
B	---	B	B	B	19
---	B	---	B	B	76
B	---	---	B	B	1
---	---	B	---	B	64
---	B	B	---	B	1
B	---	B	---	B	6
---	B	---	---	B	1
---	---	---	B	---	49
---	---	B	B	---	11
B	---	B	B	---	3
---	B	---	B	---	34
---	---	B	---	---	11
---	B	B	---	---	2
B	---	B	---	---	3
---	B	---	---	---	3
4.1%	19.5%	30.1%	56.1%	82.4%	661

TABLE 7.—PERFORMANCE RECORDS OF INDIVIDUAL SPURS FROM A WINESAP TREE GROWN IN LOESS SOIL

1913	1914	1915	1916	1917	No. of Spurs
....	....	....	....	B	102
....	....	....	B	B	56
....	....	B	B	B	21
....	B	B	B	B	8
B	....	B	B	B	5
....	B	....	B	B	14
B	B	....	B	B	5
....	....	B	....	B	27
....	B	B	....	B	9
B	....	B	....	B	7
....	B	....	....	B	3
....	....	....	B	....	34
....	....	B	B	....	10
....	B	B	B	....	4
B	....	B	B	....	1
....	B	....	B	....	6
B	B	....	B	....	2
....	....	B	....	....	1
6.0%	16.1%	28.8%	55.8%	81.6%	315

TABLE 8.—PERFORMANCE RECORDS OF INDIVIDUAL SPURS FROM A ROME TREE GROWN IN CLAY LOAM SOIL

1913	1914	1915	1916	1917	No. of Spurs
....	....	....	....	B	3
....	....	B	....	B	1
....	....	....	B	....	428
....	....	B	B	....	48
....	B	B	B	....	4
B	....	B	B	....	2
....	B	....	B	....	313
B	B	....	B	....	2
B	....	....	B	....	1
....	....	B	....	....	95
....	B	B	....	....	4
B	....	B	....	....	13
....	B	....	....	....	5
1.9%	35.7%	18.1%	86.8%	0.3%	919

TABLE 9.—PERFORMANCE RECORDS OF INDIVIDUAL SPURS FROM A YORK TREE GROWN IN CLAY LOAM SOIL

1913	1914	1915	1916	1917	No. of Spurs
....	....	....	....	B	81
....	....	....	B	B	2
....	....	B	B	B	1
....	B	....	B	B	3
....	....	B	....	B	48
....	B	B	....	B	1
B	....	B	....	B	23
B	....	....	....	B	7
....	....	....	B	....	11
....	....	B	B	....	4
....	....	B	....	....	8
B	....	B	....	....	1
6.3%	2.1%	45.2%	11.2%	87.3%	190

TABLE 10.—PERFORMANCE RECORDS OF INDIVIDUAL SPURS FROM A YORK TREE GROWN IN LOESS SOIL

1913	1914	1915	1916	1917	No. of Spurs
....	....	....	....	B	47
....	....	....	B	B	5
....	....	B	....	B	4
B	....	B	....	B	1
B	....	....	....	B	1
....	....	....	B	....	180
....	....	B	B	....	31
....	B	B	B	....	2
B	B	B	B	....	1
....	....	B	B	....	22
B	....	B	B	....	4
....	B	....	B	....	5
....	....	B	....	....	17
....	B	B	....	....	1
B	....	B	....	....	1
....	B	....	....	....	3
B	B	....	....	....	1
2.7%	3.9%	25.7%	76.7%	14.7%	326

TABLE 11.—PERFORMANCE RECORDS OF INDIVIDUAL SPURS FROM A GANO TREE GROWN IN CLAY LOAM SOIL

1913	1914	1915	1916	1917	No. of Spurs
---	---	---	---	B	7
---	---	B	---	B	1
---	---	---	B	---	1047
---	---	B	B	---	8
---	B	B	B	---	4
B	---	B	B	---	2
---	B	---	B	---	545
B	---	---	B	---	26
---	---	B	---	---	47
---	B	B	---	---	1
B	---	B	---	---	6
---	B	---	---	---	130
B	B	---	---	---	3
B	---	---	---	---	37
3.9%	36.4%	3.6%	87.1%	0.5%	1864

TABLE 12.—PERFORMANCE RECORDS OF INDIVIDUAL SPURS FROM A GANO TREE (No. 1) GROWN IN LOESS SOIL

1913	1914	1915	1916	1917	No. of Spurs
---	---	---	---	B	2
---	---	---	B	B	4
---	B	---	B	B	2
---	---	---	B	---	159
---	---	B	B	---	1
B	---	B	B	---	1
---	B	---	B	---	43
B	B	---	B	---	1
---	B	B	---	---	1
B	---	B	---	---	3
---	B	---	---	---	1
2.3%	20.9%	2.6%	97.2%	3.6%	218

TABLE 13.—PERFORMANCE RECORDS OF INDIVIDUAL SPURS FROM A GANO TREE (No. 2) GROWN IN LOESS SOIL*

1913	1914	1915	1916	1917	No. of Spurs
---	---	---	---	B	22
---	---	---	B	B	51
---	B	---	B	B	35
B	---	---	B	B	1
---	---	B	---	B	6
B	---	B	---	B	1
---	B	---	---	B	4
---	---	---	B	---	83
---	---	B	B	---	8
B	---	B	B	---	1
---	B	---	B	---	15
B	B	---	B	---	1
B	---	---	B	---	1
---	---	B	---	---	1
2.1%	23.9%	7.4%	85.2%	52.1%	230

*Blossoms practically all destroyed in 1916 by spray solution. (See page 24 for further explanation).

An examination of the preceding tables shows that the varieties studied may be divided roughly into two classes, one of which produces a fair supply of blossoms each year but with no exceedingly productive seasons, while the other exhibits a very high percentage of blossoms one season and a comparatively low one the next. Jona-

than, Winesap, and Grimes belong to the former, and Rome, York, and Gano to the latter group. The varieties of the first group are usually considered as annual bearers, while the others show rather marked alternation.

The difference in the behavior of these two groups is brought out more clearly in Table 14, which is a summary of the preceding tables.

TABLE 14.—PERCENTAGE OF FRUIT SPURS BLOSSOMING IN THE VARIOUS SEASONS.
(1913-1917)
(Summary of Tables 3 to 13.)

Variety	Soil Type Where Grown	Total No. of Spurs	Percentage Distribution of Blossoms				
			1913	1914	1915	1916	1917
Jonathan	Clay Loam	1346	9.0	21.1	40.1	37.3	70.7
Jonathan	Loess	557	3.4	11.3	20.4	61.6	58.7
Grimes	Clay Loam	901	8.3	4.4	42.7	17.2	57.0
Winesap	Clay Loam	661	4.1	19.5	30.1	56.1	82.4
Winesap	Loess	315	6.0	16.1	28.8	55.8	81.6
Rome	Clay Loam	919	1.9	35.7	18.1	86.8	0.3
York	Clay Loam	190	16.3	2.1	45.2	11.2	87.3
York	Loess	326	2.7	3.9	25.7	76.7	14.7
Gano	Clay Loam	1864	3.9	36.4	3.6	87.1	0.5
Gano No. 1	Loess	218	2.3	20.9	2.6	97.2	3.6
Gano No. 2*	Loess	230	2.1	23.9	7.4	85.2	52.1

*Blossoms practically all destroyed in 1916 by spray solution.

It will be noted that the behavior in 1917 of the spurs on the tree, Gano No. 2, is in apparent contradiction to that of Gano No. 1. This may be explained by the fact that in 1916, at which time both trees had a heavy bloom, the spraying operations were so delayed that it was necessary to spray tree No. 2 when it was in full blossom. As a result, only a very small percentage of the blossoms set fruit, hence the spurs were able to mature fruit buds for the following year. That they did so, is evidenced by the amount of blossom carried by the tree in 1917. It is thus seen, notwithstanding the statements of some investigators to the contrary, that the bearing year may be changed, and, to this extent, is subject to the control of the horticulturist.

Attention is also called to the fact that the York tree growing in loess soil, produces its blossoms in the season alternating with the heavy fruit crop of the tree in the clay loam soil. Even in the same orchard this same variation in behavior is sometimes found. In each case, however, marked alternation is shown. It gives strength

to the statement sometimes made that when alternation is once established, there is a great likelihood that it will be continued thru the following years, unless interrupted by accident or design.

Outside of the foregoing exceptions the varieties show very great similarity in their behavior in the different soil types. This is at least suggestive of the conclusion that after all the soil conditions do not affect markedly the behavior of the individual spurs with respect to their individual alternation.

With the idea of showing a little more clearly the behavior of the individual spurs, Tables 15 and 16 have been prepared. The first table indicates the percentage of the spurs now on the tree, which have produced blossom buds in successive seasons, while the second table shows the percentage of spurs which have blossomed in alternate years.

TABLE 15.—PERCENTAGE OF SPURS BLOSSOMING IN ALTERNATE SEASONS

Variety	Soil Type Where Grown	Total No. of Spurs	Percentage Blooming in			Total Percentage Showing Alternation
			1913-15	1914-16	1915-17	
Jonathan	Clay Loam	1346	0.6	7.6	26.6	34.8
Jonathan	Loess	557	0.3	8.0	10.7	19.0
Grimes	Clay Loam	901	2.7	1.3	21.8	25.8
Winesap	Clay Loam	661	0.4	5.1	10.9	16.4
Winesap	Loess	315	0.0	2.5	13.6	16.1
Rome	Clay Loam	919	1.4	34.2	0.1	35.7
York	Clay Loam	190	0.0	0.0	37.9	37.9
York	Loess	326	0.0	1.5	1.5	3.0
Gano	Clay Loam	1864	0.2	28.7	0.0	28.9
Gano No. 1	Loess	218	1.4	20.1	0.0	21.5
Gano No. 2*	Loess	230	0.0	7.4	3.0	10.4

*Blossoms practically all destroyed in 1916 by spray solution.

TABLE 16.—PERCENTAGE OF SPURS BLOSSOMING IN SUCCESSIVE SEASONS

Variety	Soil Type Where Grown	Total No. of Spurs	Percentage Blooming in			Total Percentage Showing Succession
			1914-15	1915-16	1916-17	
Jonathan	Clay Loam	1346	0.3	4.6	14.1	19.0
Jonathan	Loess	557	0.0	2.1	23.5	25.6
Grimes	Clay Loam	901	1.3	1.9	3.9	7.1
Winesap	Clay Loam	661	0.3	2.1	43.1	45.5
Winesap	Loess	315	0.0	4.7	31.4	36.1
Rome	Clay Loam	919	0.3	5.8	0.0	6.1
York	Clay Loam	190	0.0	2.1	3.1	6.2
York	Loess	326	0.3	18.3	1.5	20.1
Gano	Clay Loam	1864	0.0	0.8	0.0	0.8
Gano No. 1	Loess	218	2.7	0.9	0.4	4.0
Gano No. 2*	Loess	230	37.8	2.9	0.0	40.7

*Blossoms practically all destroyed in 1916 by spray solution.

From Table 15 it will be noted that there are relatively slight differences between the different varieties in regard to the percentage the Jonathan tree, a regular bearer, has as great a percentage of age of spurs which alternate in their blooming habit; in other words, spurs which bloom only once in two years as the Gano, which is notorious as an alternate cropper. When trees grown on similar soils are compared, the difference is very slight, the only exception occurring in the case of the Winesap. The Winesap is really one of our most reliable regular annual bearers and an explanation for this may rest in the fact that only a small percentage of the spurs do alternate in their blooming habit. Gano No. 2 also shows a slight variation from the average as do also the York and Jonathan grown upon loess soil. This is perhaps to be expected since these trees as yet have hardly attained a fully established bearing age.

Table 16 exhibits by no means such close agreement of varieties as that noted for the preceding one but rather the varieties are again divided into two general groups. With the apparent exception of the Grimes, the varieties producing regular crops possess to a marked degree the ability to produce a blossom on the same spur two years in succession. This ability is exhibited to a higher degree in the Winesap than in the Jonathan, a performance which might be expected because of the small percentage of Winesap spurs which show alternation.

Examination of the performance records of the second group of varieties shows that only a very small proportion of the spurs are able to produce successive crops of blooms. The York grown in loess soil is seemingly an exception, as is also Gano No. 2. The latter case, however, is fully explained by the fact that the 1916 crop of blossoms was practically destroyed, and hence, the tree was able to mature a larger number than normal in 1917. In the case of the York, it may be said that local environmental conditions, as well as the younger age of the tree, probably played a very important part.

The fact brought out just above, which is that spurs on varieties which bear regularly are able to produce blossoms two years in succession in a high percentage of cases while alternate bearers are not, suggests an explanation for the figures recorded in Table 14. The regularity of the blossom in the case of the first group is conceivably due to the fact that a great many of the spurs are able to produce blossoms two years in succession. Also, the inability of the second group of varieties to blossom two years in succession coupled with their exceedingly heavy production of blossoms one year will

TABLE 17.—RELATIVE NUMBER OF SPURS OF VARIOUS AGES ON APPLE VARIETIES

Variety	Soil Type Where Grown	Total No. of Spurs	Percentage Distribution of Spurs of Different Ages										
			2 yrs.	3 yrs.	4 yrs.	5 yrs.	6 yrs.	7 yrs.	8 yrs.	9 yrs.	10 yrs.	11 yrs.	12 yrs.
Jonathan.....	Clay Loam	1346	7.9	15.4	15.4	24.3	9.3	16.7	4.1	3.8	1.7	0.1	0.3
Jonathan.....	Loess	557	0.0	19.3	24.0	27.4	17.7	9.0	2.3	0.2	0.2	0.0	0.2
Grimes	Clay Loam	901	0.0	3.0	18.3	25.8	25.6	17.1	7.6	1.5	0.8	0.0	0.0
Winesap	Clay Loam	661	0.0	22.8	13.6	16.3	8.2	15.9	9.7	5.6	5.7	0.0	2.1
Winesap	Loess	315	3.5	38.1	26.6	22.5	6.9	1.2	0.0	0.0	0.0	0.0	0.0
Rome	Clay Loam	919	0.0	12.4	31.7	8.7	15.3	18.5	7.7	4.0	1.5	0.0	0.0
York	Clay Loam	190	4.2	20.0	30.5	21.5	15.8	6.8	0.5	0.5	0.0	0.0	0.0
York	Loess	326	0.0	33.1	34.3	17.4	8.9	6.1	0.0	0.0	0.0	0.0	0.0
Gano No. 1	Clay Loam	1864	2.3	17.5	23.1	27.1	14.0	8.4	3.7	1.6	1.6	0.5	0.1
Gano No. 1	Loess	218	0.0	46.8	18.8	22.0	6.4	4.5	1.4	0.0	0.0	0.0	0.0
Gano No. 2*	Loess	230	0.0	23.9	37.4	29.2	8.2	1.3	0.0	0.0	0.0	0.0	0.0

*Blossoms practically all destroyed in 1916 by spray solution.

account for the small number of blooming spurs during the following season. Thus, the difference between alternating and non-alternating varieties seems to be due to the ability of spurs on the regular bearing sorts to blossom two years in succession.

While recording the performance record of the spurs, an attempt was also made to approximate their age by counting the number of scale scar rings upon the spur. In some instances the age given is simply an estimate. This is especially the case with the old spurs because after the age of six or seven is reached, it becomes difficult to be absolutely positive as to just how old the spur may be. Table 17 will serve to show the relative ages of the blossoming spurs on the various varieties.

It is of interest to observe that by far the greater part of the blossoming spurs in every case are between three and seven years of age. This holds true for both alternating and regular bearing sorts and hence leads to the conclusion that the age at which the spur begins to bear is of little significance in relation to the bearing habit of the variety.

Because of the youthfulness of a large part of the spurs, it is again noted that by far the greater part of the spurs present on the trees when these observations were begun are spurs no longer. They have developed into branches and many new spurs have been formed. A spur seems to be at its highest state of efficiency when from three to six or seven years of age.

THE FOOD RESERVES OF FRUIT SPURS

The amount of available plant food has long been considered as the determining factor in fruit bud formation but there seems to be very little evidence or actual data to support this view. It then has seemed worth while to compare as far as possible the plant food reserves of fruiting and non-fruiting spurs and their various parts, that is, their leaves and fruits.

There are two general methods by which the relative amounts of stored food in plant tissue may be determined, the first, by determining the concentration of the plant sap thru the use of the freezing point method, and the second, by making an actual chemical analysis of the parts under consideration. The former method was used extensively by both Chandler²⁵ and Winkler¹⁴⁸ at this Station, while the English investigators, Davis and Daisch³⁸ employed the latter in the determination of plant carbohydrates. In the first method, it is not possible to calculate the absolute amount of materials

present, only the relative proportions are indicated. Neither can the amount of starch be determined by this method. Through the use of the analytical method, however, both the identity and absolute amounts of the substances present can be determined if suitable methods are employed. Both methods have been used in this investigation, but, in either case, only for the determination of the relative amounts of the reserves rather than their absolute percentages.

1. **Depression of the freezing point.**—The sap for the determination of the freezing point depression was secured by grinding up the parts under consideration by means of a food chopper and then subjecting the ground material to considerable pressure. The material was enclosed in muslin before being placed in the pressing blocks. These blocks were of hardwood and so made that one of them just fit into a cavity in the side of the other. A jackscrew served as a means by which the pressure was applied. Figure 2 shows the various details of the press. The expressed sap was collected into a test-tube thru a small funnel.

After being expressed the sap was kept in a cool place until its freezing point could be determined. An ordinary Beckman thermometer was used and the low temperature secured thru the use of a salt and ice mixture. A small amount of sap was placed in a test tube, the amount being just sufficient to cover the bulb of the thermometer. The thermometer was then inserted and the tube plunged into the salt and ice. It was usually found to be advisable not to have this tube in direct contact with the ice because the cooling in that case was too rapid. Best results were secured by first inserting into the freezing mixture a tube slightly larger than the one containing the sap, and then placing the latter inside the former. An air jacket then surrounds the tube containing the sap and the thermometer. This will slightly retard the cooling and thus insure a more uniform cooling.

The depressions given in the following tables represent the difference between the freezing point of distilled water and the freezing point of the particular sap. The plant saps, being of a higher concentration, freeze at a lower temperature. The greater this concentration, the lower will be the freezing point, and hence, the greater the depression. It is assumed that the saps with the greater depression possess the greater supply of plant food. No attempt has been made to calculate the osmotic strength of the various saps but this could be very easily done by reference to the osmotic strength tables worked out by Harris and Gortner^{62 68}.

Table 18 indicates the depressions which were found in the spur sap from spurs bearing or non-bearing in the years specified. In every case, an attempt was made to get spurs representative of these two conditions, the spurs being taken from the same branch as far as possible. Only the short fruiting branches were used, rarely were they more than three inches long. So far as outward appearance was concerned, the only difference between the two sets of spurs was that one group had fruited in the year specified and the other had not. After the spur material was ground, the sap was expressed as previously described.

TABLE 18.—DEPRESSION OF JONATHAN FRUIT SPUR SAP

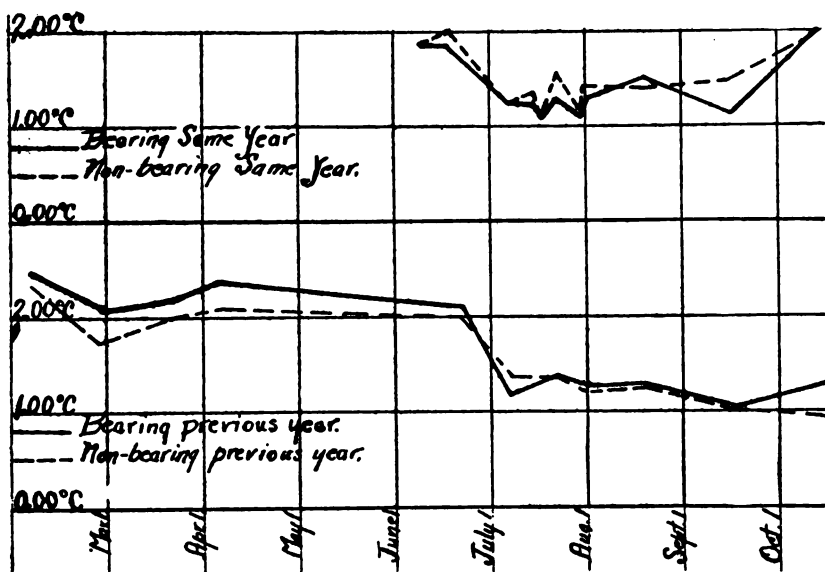
Date	Bearing previous year	Non-bearing previous year	Bearing same year	Non-bearing same year
	Degrees C.	Degrees C.	Degrees C.	Degrees C.
February 6, 1915.....	2.450	2.300	.....	.....
February 27, 1915.....	2.100	1.730	.....	.....
March 19, 1915*.....	2.120	1.990	.....	.....
April 4, 1915*.....	2.370	2.170	.....	.....
June 8, 1915.....	.....	.....	1.865	1.855
June 21, 1916.....	2.130	2.000	1.860	2.000
July 6, 1916.....	1.200	1.340	1.200	1.200
July 15, 1915*.....	.....	.....	1.200	1.330
July 17, 1915.....	.....	.....	1.060	1.070
July 22, 1916.....	1.355	1.340	1.225	1.530
July 31, 1915.....	.....	.....	1.010	1.110
August 1, 1916.....	1.265	1.210	1.250	1.400
August 17, 1916.....	1.285	1.215	1.500	1.370
September 15, 1916.....	1.080	1.040	1.205	1.435
October 14, 1916.....	1.290	0.910	1.995	1.945

*Spurs from trees grown in loess soil.

A study of the figures in Table 18 shows that during a considerable portion of the year the sap from the bearing spurs and also sap from spurs fruiting during the preceding season, has a greater depression than sap from corresponding nonfruiting parts. This difference may not be large enough to be of special significance. It gives no conclusive proof to the claim that in a non-fruiting year the spur is accumulating reserves for the next year's crop of buds. However, it may be possible that the greater part of the reserves are stored farther back from the end of the branch. Then, too, these data do not include a measure of the reserves which are stored up as starch.

The accompanying chart shows graphically the depressions recorded in Table 18. It is noticed that the sap of non-fruiting spurs is slightly more concentrated than the sap of a spur holding a fruit

at that particular time. On the other hand, sap from spurs bearing the year previous to the determination shows consistently a greater concentration than the sap from corresponding parts that did not fruit during the preceding season. This difference gradually disappears, however, and apparently both kinds of spurs reach a similar degree of concentration about July 1.



Depression of Jonathan spur sap

Marked seasonal variations in the sap density are also observed. The greatest change comes in late June and early July, at which time there is a sudden drop in concentration. This is the season at which the fruit buds for the next year's crop are forming and this abrupt drop may be either the cause or an effect of this fruit bud formation. It is noticeable in both the bearing and non-bearing spurs.

Apparently there is little difference in the concentration of the spur sap which can be attributed directly to soil conditions. Spurs from trees grown in two widely varying soil types showed little variation in the depression of the sap. Also, altho all of the above determinations were made upon sap from a Jonathan tree, there seems to be little varietal variation in this respect as the later determinations show.

The observations noted above concerning the difference in sap density in fruiting and non-fruiting parts at once opens up the question as to whether this condition may not be due to a withdrawal of

moisture from the spur by the ripening fruit or by the leaves—a deficiency which may not be altogether overcome by the following spring. Chandler²⁵ has observed that toward the ripening period water may be drawn from the fruit to the leaves. There may also be a similar movement of moisture from the spur which would at once have its effect upon the concentration of the sap of the spur.

The above determinations are perhaps too meager to warrant any positive conclusions but they are given as being suggestive of the idea that perhaps after all the food supply is not so important as has been assumed by some writers.

Leaf sap taken from leaves on fruiting and non-fruiting spurs did not show so consistent a difference as sap from the spurs themselves. The variations in these depressions, as shown in Table 19 are so great that it seems unwise to suggest any possible explanation.

TABLE 19.—DEPRESSION OF LEAF SAP FROM BEARING AND NON-BEARING JONATHAN FRUIT SPURS

Date	Fruiting Condition			
	Bearing 1915	Non-bearing 1915	Bearing 1916	Non-bearing 1916
	Degrees C.	Degrees C.	Degrees C.	Degrees C.
June 21, 1916	2.680	2.690	2.550	2.880
July 15, 1915	1.510	1.590		
July 22, 1916	1.970	1.980	2.035	2.015
August 1, 1916	1.605	1.890	1.510	2.100
August 17, 1916	2.340	2.205	2.540	2.290
September 15, 1916	2.255	1.995	2.190	2.460
October 14, 1916	1.995	1.945	2.260	2.110

TABLE 20.—DEPRESSION OF SPUR SAP FROM SPURS BEARING 3, 2, 1, OR NO FRUITS

Date	Variety	Fruiting Condition			
		3 fruits	2 fruits	1 fruit	no fruit
		Degrees C.	Degrees C.	Degrees C.	Degrees C.
June 8, 1915.....	Jonathan	1.905	1.860	1.865	1.855
June 21, 1916 ...	Woodmansee	2.060	2.040	2.010	
July 6, 1916.....	Woodmansee	1.250	1.340	1.160	
July 15, 1915.....	Jonathan*		1.130	1.200	1.330
July 17, 1915.....	Jonathan		0.950	1.060	1.070
July 17, 1915.....	York*		1.200	1.130	1.300
July 22, 1916.....	Woodmansee	1.365	1.310	1.225	
July 31, 1916.....	Jonathan		0.920	1.010	1.100
August 1, 1916.....	Woodmansee	1.270	1.295	1.510	
July 17, 1916.....	Woodmansee	1.600	1.535	1.500	
September 15, 1916	Woodmansee	1.360	1.450	1.205	

*Spurs from trees grown in loess soil.

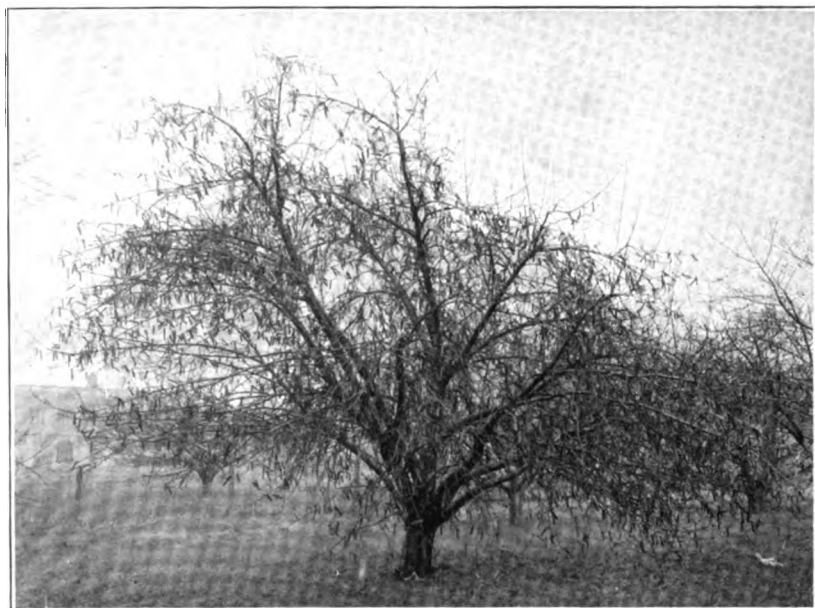


Fig. 1.—Gano apple tree on which some of the labeling work was done

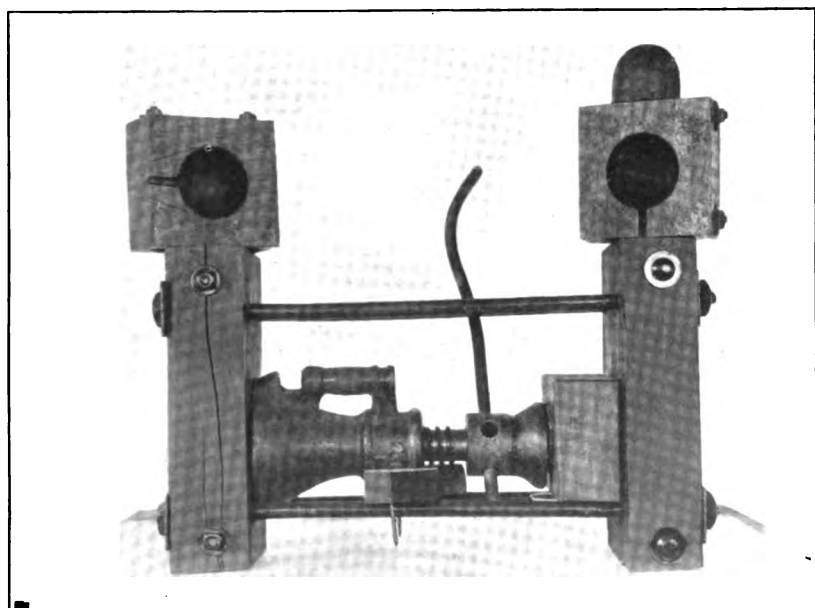


Fig. 2.—Press and blocks by means of which the plant saps were expressed

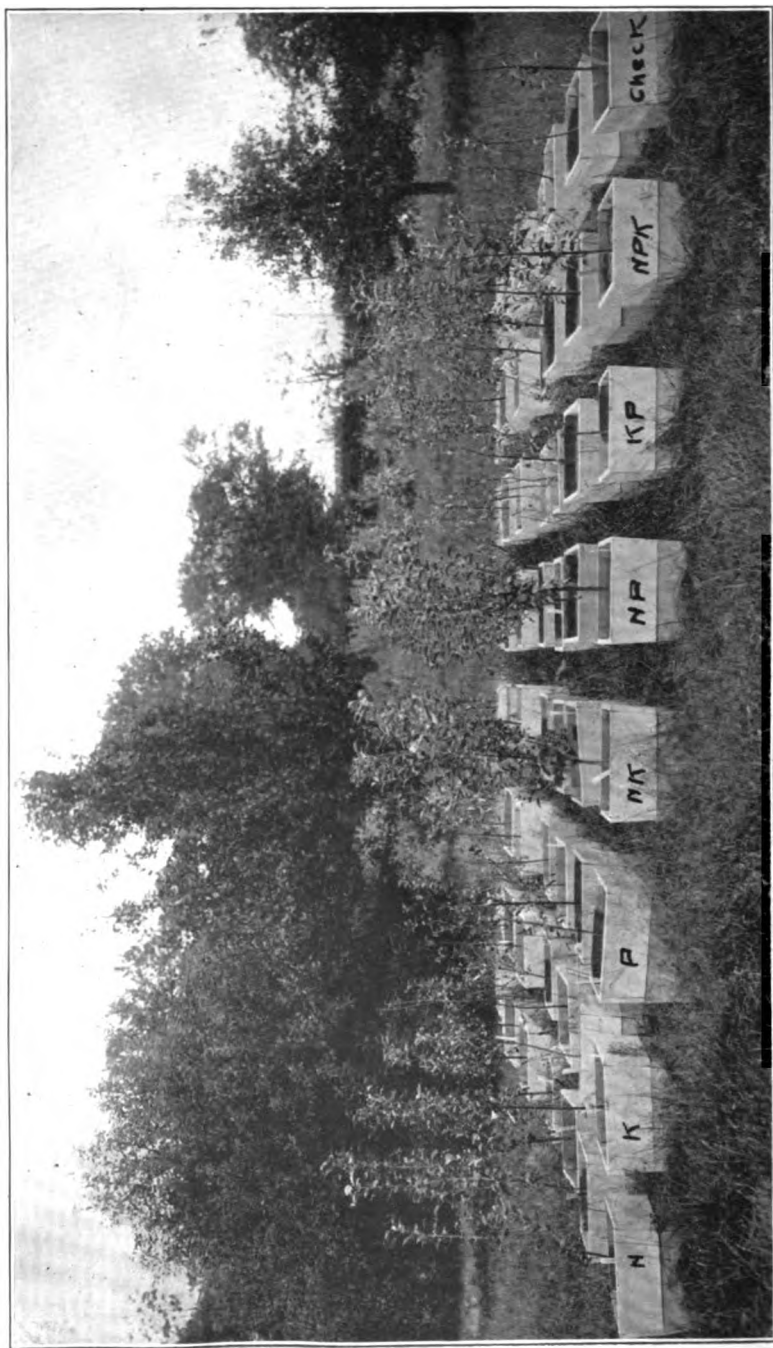


Fig. 3.—Dwarf apple trees after one season's growth. Note the very marked effects of nitrogen

Also figures on the depression of spur sap, leaf sap, and fruit sap from spurs bearing three, two, and one fruits, are so inconsistent as to be of no assistance in helping to explain fruitfulness or non-fruitfulness. In general, it may be stated that it apparently makes little or no difference upon the concentration of the sap as to how many fruits a spur is maturing. The seasonal differences in the depression of the fruit spur sap are again brought out by Table 20 which checks very well with Table 18 in this respect.

TABLE 21.—DEPRESSION OF LEAF SAP FROM SPURS BEARING 3, 2, OR 1 FRUITS

Date	Variety	Fruiting Condition		
		3 fruits	2 fruits	1 fruit
		Degrees C.	Degrees C.	Degrees C.
June 21, 1916.....	Woodmansee	2.660	2.610	2.580
July 6, 1916	Woodmansee	1.930	1.790	1.830
July 15, 1915	Jonathan	.....	1.510	1.510
July 22, 1916.....	Woodmansee	1.940	1.830	2.035
August 1, 1916	Woodmansee	1.895	1.870	2.135
August 17, 1916	Woodmansee	2.650	2.550	2.540
September 15, 1916	Woodmansee	2.640	2.045	2.190

TABLE 22.—DEPRESSION OF FRUIT SAP FROM SPURS BEARING 3, 2, OR 1 FRUITS

Date	Variety	Fruiting Condition		
		3 fruits	2 fruits	1 fruit
		Degrees C.	Degrees C.	Degrees C.
June 8, 1915	Jonathan	1.000	.960	.950
June 21, 1916.....	Woodmansee	1.880	2.040	1.900
July 6, 1916	Woodmansee	1.180	1.040	1.040
July 22, 1916	Woodmansee	1.325	1.345	1.290
August 1, 1916	Woodmansee	1.325	1.330	1.320
August 17, 1916	Woodmansee	1.395	1.440	1.320
September 15, 1916	Woodmansee	1.415	1.435	1.355

2. **Chemical Determinations.**—In order to get at the problem from a different angle and to compare especially the relative amounts of sugars and starch in the spurs, it was decided to employ some simple chemical methods. The method used in the sugar analysis was adapted very largely from the work of Davis and Daish³³ and the starch determination was made in accordance with the directions in standard works on agricultural analysis. While these determinations possibly may not be all that might be desired from the chemical point of view, they are at least comparative and it is this connection that they are of value here.

Considerable difficulty was encountered in securing satisfactory results, and, altho the work was begun early in 1917, several months had passed before it was felt that results of any reliability were obtained. The results given below were secured from spur material only, since the buds alone or the leaves could not be used satisfactorily.

The analyses were carried out according to the following plan:

1. Grind the material with a food chopper and then weigh out a 15-gram sample.
2. Boil the sample for one hour in 500 cc. of 95 per cent alcohol to which had been added 5 cc. of ammonium hydroxide.
3. Filter and wash the residue with alcohol. Preserve the filtrate for the sugar determinations. Dry the residue for the starch determination.
4. Add 2 cc. of toluene to the filtrate and evaporate down to 40-50 cc. at 70°C. Dilute to 250 cc. with water.
5. Precipitate the tannins in 200 cc. with basic lead acetate (sp. gr. 1.25), adding a small excess of this material. Make up to 250 cc. and filter.
6. To 200 cc. of this filtrate, add enough solid sodium carbonate to remove the excess basic lead acetate. Again make up to 250 cc. and filter.
7. To 25 cc. of this filtrate add a small amount of Fehling's Solution, boil for two minutes and then filter. Dry and weigh the cuprous oxide precipitate. This gives a measure of the amount of *reducing* sugar present.
8. To another 25 cc. sample add enough sulphuric acid to make it faintly acid to methyl orange. Then add 10 per cent by weight of citric acid crystals. Boil for ten minutes and then neutralize to phenolphthalein with sodium hydroxide. Add a sufficient quantity of Fehling's Solution to precipitate the *total sugars* as cuprous oxide. Filter, dry and weigh the precipitate.
9. Two and one-half grams of the residue from procedure No. 3 are placed in a flask with 200 cc. of water and 20 cc. of hydrochloric acid (sp. gr. 1.125). It is then boiled in a reflux condenser for two and one-half hours. One cc. of toluene is added after it cools.
10. Nearly neutralize with sodium hydroxide, using phenolphthalein as an indicator. Dilute to 250 cc.
11. Add Fehling's Solution to 25 cc., boil for two minutes, then dry and weigh the cuprous oxide precipitate. This indicates the amount of *starch* present. Pentoses and pentosans are also included.

The results secured are given in Table 23. No attempt has been made to calculate the actual percentage of sugars or starch present. The figures represent only the weight of cuprous oxide present in the aliquots indicated. All determinations were made upon the spurs of a Yellow Transparent tree. This variety was selected because of the accuracy with which the past performance of the spurs could be determined.

TABLE 23.—SUGAR AND STARCH CONTENT OF YELLOW TRANSPARENT FRUIT SPURS

Date of Determination	Condition of Spur	Weight of Cuprous Oxide Representing		
		Reducing Sugar	Total Sugar	Starch
October 22, 1917	Bearing	.0153	.0447	.1861
	Non-bearing	.0191	.0502	.1815
November 3, 1917	Bearing	.0167	.0530	.1605
	Non-bearing	.0215	.0488	.1730
November 17, 1917	Bearing	.0720*	.0760	.1569
	Non-bearing	.0150	.0780	.1560
December 1, 1917	Bearing	.0594	.0800	.1336
	Non-bearing	.0615	.0690	.0990
December 19, 1917	Bearing	.0305	.0727	.1332
	Non-bearing	.0477	.0877	.1477
January 3, 1918	Bearing	.0300	.0700	.1500
	Non-bearing	.0384	.0800	.1500
January 24, 1918	Bearing	.0255	.0530	.1395
	Non-bearing	.0520	.0965	.0915
February 11, 1918	Bearing	.0335	.0780	.1145
	Non-bearing	.0325	.0750	.1325
March 6, 1918	Bearing	.0320	.0855	.1685
	Non-bearing	.0400	.1000	.1585
March 20, 1918.....	Bearing	.0225	.0740	.1355
	Non-bearing	.0180	.0500	.0975
April 3, 1918	Bearing	.0170	.0325	.1505
	Non-bearing	.0275	.0540	.1505

*It is very probable that a portion of the non-reducing sugar is also included in this determination.

The number of determinations is small and the series incomplete in that there are no figures available for the important summer months preceding and during the time of fruit bud formation. Positive conclusions probably should not be formulated but the data are at least suggestive. It will be noticed that in a majority of the cases there seems to be a slightly greater amount of sugar, both reducing and total, in the non-bearing spurs. The starch content of the non-bearing spurs, however, does not average quite so high as in the bearing spurs but there is considerable variation in these results. The amount of starch apparently decreases somewhat, in both kinds of spurs, as the growing season approaches, while the amount of sugars increases.

Judging from these few determinations, some emphasis is given to the theory that the non-bearing spurs are able to lay up a greater amount of reserves than spurs which are maturing fruits. When compared with the total amount of reserves, however, this excess is very small. These results do not agree altogether with those secured from the freezing point determinations. The latter, however, gave a

measure of soluble materials only. If the conclusion reached by Magness⁸⁹, that reserves are stored near the point of synthesis, is a true one, then it would seem that the non-bearing spur accumulates only a slightly greater reserve supply than the fruiting spur. This difference, however, may be sufficient to account for the lack of fruit bud formation on such a large percentage of bearing branches.

NUMBER OF LEAVES AND LEAF AREA OF FRUIT SPURS

General observation long ago led to the conclusion that spurs maturing fruits had a smaller leaf area than adjacent spurs having no fruit upon them. In order to secure some definite idea as to the degree of this difference, some counts and measurements of the leaves on fruit spurs have been taken.

Counts made in 1915 gave the following figures concerning the number of leaves on the spurs. Several varieties were used, the number of spurs taken being large enough to be representative of the tree as a whole. In every case, as will be seen from Table 24, the non-bearing spur has the greater number of leaves, when averages are taken.

TABLE 24.—NUMBER OF LEAVES ON BEARING AND NON-BEARING FRUIT SPURS

Variety	Average Number of Leaves on Each Spur	
	Bearing	Non-bearing
Ben Davis	8.70	8.66
Jonathan	7.98	9.14
Ingram	9.38	9.85
Minkler	8.32	8.46

In the next two seasons further counts and also some measurements were made, the leaf area being determined by the use of a polar planimeter. A summary of these results is given in Table 25. These data represent the figures secured from the measurements of more than two hundred and fifty spurs and hence may be taken as representative. It will be noted that from the average total leaf surface of the spur and the average number of leaves, the average size of the individual leaf has been calculated.

To give some idea of the range of variation found in both the number of leaves on a single spur and their total area, the figures on a few spurs taken at random from Jonathan and Woodmansee trees are also given. (Tables 26 and 27.)

TABLE 25.—AVERAGE NUMBER OF LEAVES AND AMOUNT OF LEAF SURFACE ON BEARING AND NON-BEARING SPURS

Variety	Bearing Spurs			Non-bearing Spurs		
	No of Leaves	Total area	Av. Leaf Size	No of Leaves	Total area	Av. Leaf Size
		sq. in.	sq. in.		sq. in.	sq. in.
Doctor	6.10	13.72	2.25	7.40	20.80	2.81
Summer Colville	4.36	15.67	3.59	5.75	21.70	3.77
Eper	6.16	9.86	1.57	8.15	13.66	1.67
Woodmansee	4.38	6.83	1.55	6.16	13.67	2.21
Ben Davis	5.38	11.25	2.08	6.66	15.39	2.31
Missouri	5.36	6.96	1.29	7.64	9.89	1.29
Jonathan	6.65	10.83	1.62	8.41	14.58	1.73

TABLE 26.—NUMBER AND SIZE OF LEAVES ON BEARING AND NON-BEARING JONATHAN FRUIT SPURS

Bearing			Non-bearing		
Spur No.	No. of Leaves	Total Leaf Area	Spur No.	No. of Leaves	Total Leaf Area
		sq. in.			sq. in.
1	7	15.76	1.....	5	9.49
2	7	9.69	2.....	8	12.30
3	10	17.53	3.....	6	10.40
4	9	12.48	4.....	9	13.34
5	5	8.45	5.....	9	18.63
6	6	13.19	6.....	11	28.40
7	7	12.72	7.....	8	18.64
8	14	20.05	8.....	9	18.01
9	2	4.28	9.....	11	18.14
10	6	12.78	10.....	7	12.15

TABLE 27.—NUMBER AND SIZE OF LEAVES ON BEARING AND NON-BEARING WOODMANSEE FRUIT SPURS

Bearing			Non-bearing		
Spur No.	No. of Leaves	Total Leaf Area	Spur No.	No. of Leaves	Total Leaf Area
		sq. in.			sq. in.
1	5	8.40	1.....	6	15.05
2	4	5.41	2.....	6	11.99
3	4	7.12	3.....	5	13.57
4	3	3.82	4.....	5	11.22
5	4	6.56	5.....	4	9.23
6	3	5.05	6.....	5	11.61
7	5	9.41	7.....	6	8.80
8	7	11.80	8.....	8	21.76
9	6	7.63	9.....	9	22.20
10	5	4.73	10.....	9	18.04

In every case it is shown that non-bearing spurs have a larger number of leaves and a greater total leaf surface than non-fruiting spurs. When the average size of the individual leaf is computed, however, it is found that no very marked difference is present. It seems, therefore, that so far as the size of the individual leaf is concerned, it makes little difference whether it is upon a fruiting or non-fruiting spur. The greater total leaf area of the non-bearing part apparently comes almost wholly from the increased number of leaves which it develops.

The relative sizes of the individual leaves, and also the total leaf area, on bearing and non-bearing spurs is brought out clearly in Table 28. To get the figures given in this table, it is necessary only to divide the average individual leaf area of the non-bearing spur by that of the bearing spur. A similar operation gives the proportion between the total leaf area of non-bearing and bearing spurs.

TABLE 28.—PROPORTIONS BETWEEN NON-BEARING AND BEARING SPURS IN RESPECT TO (1) AREA OF INDIVIDUAL LEAVES, AND (2) TOTAL LEAF AREA OF THE SPUR

Variety	Individual Leaf Area	Total Leaf Area of Spur
Jonathan	1.06	1.35
Missouri	1.00	1.42
Eper	1.06	1.38
Summer Colville	1.05	1.38
Ben Davis	1.11	1.36
Doctor	1.24	1.51
Woodmansee	1.42	2.00

With the exception of Woodmansee and Doctor the varietal agreement in Table 28 is exceptionally good. Ben Davis also shows a slightly higher proportion between the sizes of individual leaves from non-bearing and bearing spurs than the more regular cropping varieties such as Missouri and Jonathan. There is just a suggestion here that this higher proportion may be correlated with alternation, for both the Ben Davis and Woodmansee are noted alternate bearers, the Woodmansee alternating probably more even than the Ben Davis. The other sorts have not fruited sufficiently long in this section for their bearing habits to be well known.

From these measurements, it is made clear that potentially, the non-fruiting spur has the much larger leaf surface from which to draw its supply of elaborated plant food. If this food is stored near the point where elaborated, then the non-fruiting spur should have the greater amount of such materials to draw upon in times of

emergency. Reasoning from this alone, it is not difficult to see why fruit buds should form more often on non-fruiting than on fruiting spurs.

EFFECTS OF GIRDLING UPON THE CONCENTRATION OF PLANT SAP

Girdling has often been recommended as a very effective means of stimulating fruitfulness. With the purpose in view to determine the actual effects of girdling as revealed by the changes brought about in the plant sap concentration, some preliminary experiments were begun in the spring of 1915. These first tests were conducted with nursery trees three years old, since it was thought the results obtained would be representative of what might occur on older trees. The number of available trees was so small, however, that a complete series of results could not be obtained at this time, so the work was continued the following season.

The trees were girdled by removing a strip of bark approximately one inch in width from the trunk of the tree, the girdle usually being quite close to the ground. Trees were girdled at regular intervals thruout the spring and early summer and the subsequent effects of the girdling noted by determining the depression of the freezing point of the saps from time to time. These depressions were determined for all parts of the tree, leaves, twigs, trunk, and roots. In the case of woody tissues, the cortex only was ground up and pressed. The sap was expressed and the freezing point determined as described above in the case of the fruit spurs. The following tables present the data secured.

TABLE 29.—EFFECT OF GIRDLING UPON THE DEPRESSION OF TRUNK SAP
1—Bark from below girdle. 2—Bark from above girdle

Date of Girdling	Depression on Date Given, 1915							
	June 1	June 19	July 7	July 28	Aug. 18	Sept. 10	Oct. 23	Nov. 20
Check	0.920	0.995	0.870	0.890	0.870	1.070	1.360	1.320
April 27	1	0.920	0.735	0.820	0.790	.....	.....	.....
.....	2	1.320	1.160	1.370	1.310	.....	.....	.....
May 29	1	.....	0.765	0.920	0.920	.....	.....	.....
.....	2	.....	1.205	1.470	1.290	.....	.....	.....
June 9	1	.....	0.785	0.720	0.830	0.660	.....	.....
.....	2	.....	1.025	1.300	1.190	1.210	.....	.....
July 1	1	.....	.....	0.800	0.780	0.520	0.630	.....
.....	2	.....	.....	1.030	1.080	1.250	1.860	.....
July 15	1	.....	.....	.....	0.820	0.650	0.850	0.930
.....	2	.....	.....	.....	0.910	1.090	1.310	1.420
July 31	1	.....	.....	.....	.....	0.810	0.910	0.750
.....	2	.....	.....	.....	.....	1.000	1.220	1.450
August 18	1	.....	.....	.....	.....	.....	0.930	0.830
.....	2	.....	.....	.....	.....	.....	1.130	1.550
September 8	1	.....	.....	.....	.....	.....	.....	0.930
.....	2	.....	.....	.....	.....	.....	.....	1.380

TABLE 30.—EFFECT OF GIRDLING UPON THE DEPRESSION OF TWIG SAP

Date of Girdling	Depression on Date Given, 1915					
	June 3	June 21	June 24	July 7	July 28	Aug. 18
Check	1.240	1.200	1.200	1.090	0.870	1.020
April 27	1.450	1.380	.....	1.370	1.050	.....
May 29 .....	.....	.....	1.450	1.300	.....	.....
June 9 .....	.....	.....	1.410	1.250	1.090	0.870
July 1 .....	.....	.....	.....	1.170	1.170	1.210
July 15 .....	.....	.....	.....	.....	1.110	1.230
July 31 .....	.....	.....	.....	.....	.....	1.150

TABLE 31.—EFFECT OF GIRDLING UPON THE DEPRESSION OF LEAF SAP

Date of Girdling	Depression on Date Given, 1915						
	June 3	June 21	July 7	July 28	Aug. 18	Sept. 10	Oct. 23
Check	1.410	1.950	1.900	1.630	1.400	2.010	2.570
April 27	2.050	2.250	2.420	2.360	.....	.....	.....
May 29 .....	.....	1.970	2.210	2.710	.....	.....	.....
June 9 .....	.....	2.270	2.270	2.020	1.825	.....	.....
July 1 .....	.....	.....	2.140	1.970	2.210	2.130	.....
July 15 .....	.....	.....	.....	1.940	1.860	1.970	2.800
July 31 .....	.....	.....	.....	.....	1.780	1.820	.....
August 18 .....	.....	.....	.....	.....	.....	2.000	2.740
September 8 .....	.....	.....	.....	.....	.....	.....	2.770

TABLE 32.—EFFECT OF GIRDLING UPON THE DEPRESSION OF ROOT SAP

Date of Girdling	Depression on Date Given, 1915						
	June 21	July 7	July 28	Aug. 19	Sept. 10	Nov. 5	Nov. 22
Check	0.830	0.740	0.750	0.900	0.960	1.120	1.310
April 27	0.640	0.720	0.500	.....	.....	.....	.....
May 29	0.680	0.570	0.610	.....	.....	.....	.....
June 9	0.690	0.550	0.630	0.800	.....	.....	.....
July 1 .....	.....	0.670	0.590	0.620	0.620	.....	.....
July 15 .....	.....	.....	0.640	0.540	0.975	0.890	1.090
July 31 .....	.....	.....	.....	0.700	0.730	0.720	0.650
August 18 .....	.....	.....	.....	.....	0.780	0.700	0.790
September 8 .....	.....	.....	.....	.....	.....	0.660	0.940

A study of the preceding tables shows rather distinctly the following features. In the case of sap from the trunk of the tree, the girdled trees had the highest concentration above the girdle and the lowest below, with the check tree intermediate. These differences were discernible almost immediately after the girdle was made, and remained consistent. However, there is evidence pointing to the conclusion that these differences grow less as the season advances. When it is considered that in many cases the girdled area had been partly

or almost entirely healed over by cambium development, this evidence is not surprising.

Twig sap from girdled trees is slightly more concentrated than that from normal trees but the difference is hardly so great as those noted above for trunk sap. Leaf sap shows more variation than either the twig or trunk sap but in a majority of the determinations the leaf sap from the girdled tree possessed the greater supply of plant food as evidenced by its lower freezing point.

Root sap differs from the other portions of the tree by having a sap of the lower concentration in the case of girdled trees.

From the foregoing it is readily seen that the sap of all parts above the girdle has an increased sap density, and that of all parts below, a decreased sap density, when compared with sap from corresponding parts of similar ungirdled trees.

Nursery trees were also used for the 1916 work, but these were four or five years old,—in fact, they were sufficiently old that some had begun to produce a small amount of fruit. The scope was broadened so that in addition to the root and trunk sap, leaf sap was secured from new growth, both above and below the girdle, and from the one-year-old spurs, potential fruiting wood, which the trees had developed. The twig sap determinations were made upon sap from the new growth both above and below the girdle and also from the one-year-old twigs.

Examinations of the trees had revealed that several specimens had been either totally or partly girdled by rabbits the previous winter (1915-16). It was decided to include these along with the newly girdled trees, to see just what effect such injury might have upon the plant sap.

The trees were girdled in a manner similar to that employed upon the earlier ones and the determinations made as noted above. The results follow:

TABLE 33.—EFFECT OF GIRDLING UPON THE FREEZING POINT
Depression of trunk sap above the girdle

Date of Girdling	Depression on Date Given, 1916					
	June 12	June 26	July 12	July 24	Aug. 7	Aug. 24
Check	1.220	1.510	1.085	1.255	2.145	2.695
Partly girdled by rabbits						
1916-17	1.430	1.340	1.280	2.025	2.255	1.715
Entirely girdled by rabbits						
1916-17	1.000	1.660	1.395	1.765	2.250	1.925
June 12		1.460	1.110	1.760	2.195	2.720
June 26			1.020	1.245	1.675	2.070
July 11				1.250	1.665	2.605
July 24					2.100	2.240
August 8						1.695

TABLE 34.—EFFECT OF GIRDLING UPON THE FREEZING POINT
Depression of twig sap

Date of Girdling	Depression on Date Given					
	June 12	June 26	July 12	July 24	Aug. 7	Aug. 24
Check—not girdled..... 1	1.930	1.260	1.130	1.085	1.720	1.495
2	2.590	1.510	1.605	1.480	1.780	1.900
3	2.000	1.800	1.640	2.200	2.210	2.665
Partly girdled by rabbits winter of 1916-17..... 1	1.560	1.440	1.030	1.585	1.445	1.405
2	2.500	1.650	1.475	1.945	1.890	1.745
3	2.540	2.030	1.375	2.260	2.330	2.355
Entirely girdled by rabbits winter of 1916-17..... 1	1.150	1.210	0.900	-----	1.450	-----
2	2.270	2.110	1.425	2.315	2.125	1.745
3	2.100	1.410	1.540	1.715	1.780	2.370
June 12 1	-----	1.060	0.735	1.425	1.810	1.920
2	-----	2.230	1.240	1.515	1.965	1.985
3	-----	2.760	1.455	2.175	2.845	3.430
June 26 1	-----	-----	0.995	-----	1.395	1.185
2	-----	-----	1.475	1.735	1.585	1.470
3	-----	-----	1.895	1.620	2.035	1.520
July 11 1	-----	-----	-----	1.010	1.790	1.405
2	-----	-----	-----	1.655	2.170	1.610
3	-----	-----	-----	1.795	3.100	2.460
July 24 1	-----	-----	-----	-----	1.285	1.300
2	-----	-----	-----	-----	2.365	1.605
3	-----	-----	-----	-----	2.490	2.280
August 8 1	-----	-----	-----	-----	-----	1.195
2	-----	-----	-----	-----	-----	1.695
3	-----	-----	-----	-----	-----	2.790

NOTE: 1—New growth below the girdle. 2—New growth above the girdle. 3—One year old twigs or spurs.

These tables may be very briefly summed up by repeating the general conclusions reached from the earlier work, which are that the parts above the girdle show a greater density, and the parts below, a lesser concentration of plant sap, than is found to be the case with check trees. The trees girdled by rabbits exhibit a behavior very similar to the other girdled trees except that the sap from the partly girdled tree is more variable. This is probably to be expected since varying amounts of the cambium had been removed from these trees. Sap from corresponding parts above and below the girdle on the same tree shows the higher concentration, with few exceptions, in the parts above the girdle. As a rule, the sap of one-year-old twigs has a greater density than sap from twigs representing the current year's growth. Leaf sap from these parts stands in the same relation as the twig sap.

That girdling does lead to increased fruitfulness is a matter of common knowledge. The foregoing data furnish one definite reason

TABLE 35.—EFFECT OF GIRDLING UPON THE FREEZING POINT
Depression of leaf sap

Date of Girdling		Depression on Date Given					
		June 12	June 26	July 12	July 24	Aug. 7	Aug. 24
Check—not girdled	1	2.940	1.710	1.915	2.265	2.240	3.010
	2	2.730	1.910	2.360	2.555	2.615	3.570
	3	2.530	2.750	2.275	2.435	2.430	3.540
Partly girdley by rabbits winter of 1916-17	1	2.230	2.160	1.780	2.310	2.325	2.420
	2	2.580	2.140	2.035	2.675	2.790	2.660
	3	2.870	2.070	2.005	2.505	2.460	3.100
Partly girdled by rabbits winter of 1916-17	1	1.490	2.020	1.515	.....	2.065	2.370
	2	3.150	2.760	2.390	2.825	2.970	2.985
	3	2.800	2.610	2.215	3.015	2.925	2.945
June 12	1	.....	1.610	.....	1.970	2.545	3.440
	2	.....	2.880	2.300	2.725	2.995	3.820
	3	.....	2.810	2.290	2.800	2.915	3.070
June 26	1	.....	.....	.....	.....	2.130	2.335
	2	.....	.....	2.545	2.530	2.855	3.010
	3	.....	.....	2.550	2.445	2.880	2.980
July 11	1	.....	.....	.....	1.975	2.145	2.955
	2	.....	.....	.....	2.555	3.015	3.655
	3	.....	.....	.....	2.705	3.175	3.785
July 24	1	.....	.....	.....	.....	1.990	2.230
	2	.....	.....	.....	.....	2.910	3.010
	3	.....	.....	.....	.....	2.820	3.260
August 8	1	.....	.....	.....	.....	.....	2.560
	2	.....	.....	.....	.....	.....	3.570
	3	.....	.....	.....	.....	.....	3.590

NOTE: 1—From new growth below the girdle. 2—From new growth above the girdle. 3—From one year old branches or spurs.

TABLE 36.—EFFECT OF GIRDLING UPON THE FREEZING POINT
Depression of root sap

Date of Girdling	Depression on Date Given					
	June 12	June 26	July 12	July 24	Aug. 7	Aug. 24
Check	0.940	1.240	1.210	1.420	1.455	2.085
Partly girdled by rabbits 1916-17	0.920	1.010	1.150	1.685	1.500	1.540
Entirely girdled by rabbits 1916-17	0.700	0.890	1.073	1.085	1.410	1.610
June 12 .....	.....	0.910	0.825	1.390	1.180	2.355
June 26 .....	.....	.....	1.075	1.080	1.250	1.810
July 11 .....	.....	.....	.....	1.245	1.675	1.940
July 24 .....	.....	.....	.....	.....	1.375	1.315
August 8 .....	.....	.....	.....	.....	.....	1.530

why this phenomenon occurs, since it is very evident that girdling does cause an increased supply of food materials to accumulate in the parts above the girdle. It is conceivable that such an accumula-

tion of reserves should result in the formation of a greater number of fruit buds. The data also indicate that girdling in early summer is likely to be most efficacious in promoting fruit bud formation since the greatest differences in concentration are evident if the girdling is done at that time.

This conclusion does not agree altogether with the data secured from the fruit spur studies in which it was found that the differences in the amount of food reserves present in bearing and non-bearing parts were very slight. However, it will be noted that girdling, severe as it is, did not cause a marked difference in the concentration of the sap of the outermost parts of the tree. The greatest effect is to be observed on the trunk sap but this difference lessens as the distance from the girdle increases. The leaves and twigs at the periphery of the tree where the fruit buds are formed do not show such great variation. This may furnish an explanation for the slight difference found in the case of the bearing and non-bearing spurs. It is entirely possible that the reserves which are responsible for fruit bud formation are brought from some point beyond the spur itself, and hence, data based upon spur sap alone may not indicate the difference which actually exists in the food supply.

THE EFFECT OF FERTILIZERS UPON FRUITFULNESS

The following experiment, begun at the Missouri Experiment Station in 1914, was designed to show the specific effects of chemical fertilizers, applied either singly or in combination, upon the fruitfulness of apples. The results are as yet incomplete, since the trees are just beginning to show some of the effects of the fertilizers. It is the plan to continue the work for several seasons, but a part of the data are of interest in connection with this investigation and for that reason are included here.

The plants used for this work were one-year-old Rome Beauty apple trees, budded upon Paradise stock. The trees were very uniform in size and appearance at the time of planting. They were set in wooden boxes 18x18 inches at the top, 16x16 inches at the bottom, and 16 inches in depth. One-half the number of boxes were filled with Missouri River sand and the other half with loess soil. The amount of sand used in each case was 75 kilograms, and of soil, 90 kilograms. Suitable samples showed that the soil contained 13.27 per cent of moisture while the sand held only 3.42 per cent.

It was thought that by planting the trees in the boxes, the effect of the fertilizers could be more readily distinguished, since there

would not be so many outside factors to be taken into consideration. For similar reasons, it was thought advisable to use sand, a medium practically free of plant food, on one medium and loess soil, a soil type well suited to fruit trees generally, for the other. Both mechanical and chemical analyses were made of the sand and of the soil. These analyses in tabular form follow:

TABLE 37.—CHEMICAL ANALYSES OF LOESS SOIL AND MISSOURI RIVER SAND*

Material	Per Cent in Loess Soil	Per Cent in Sand
Water**	1.740	.110
Total Nitrogen .....	.019	.005
Total Phosphorus .....	.073	.056
Total Potassium	1.667	1.599

*Analyses furnished by Agricultural Chemistry Department of Missouri Experiment Station.

**In air-dry material.

TABLE 38.—MECHANICAL ANALYSES OF LOESS SOIL AND MISSOURI RIVER SAND

Soil Particles	Per Cent in Loess Soil	Per Cent in Sand
Fine gravel	0.00	6.59
Coarse sand	0.00	19.05
Medium sand	0.93	35.33
Fine sand	45.79	35.31
Very fine sand	33.81	0.13
Silt	11.07	0.00
Clay	8.42	3.47

The fertilizers used have been sodium nitrate, acid phosphate, and potassium sulphate, in their common commercial forms. They were applied singly and in all possible combinations. Each plot contained eight trees, four in loess soil and four in sand. A check plot received no treatment at all. All fertilizer applications were made in the spring just as growth was beginning. The amounts used per tree were, sodium nitrate, 15 grams; acid phosphate, 30 grams; and potassium sulphate, 30 grams.

The trees have remained exposed to outside conditions from the time of planting, except that during the winter the roots have been protected somewhat from the cold by filling the spaces between the boxes with sawdust and also covering the boxes with boards. Whenever necessary, water has been supplied during summer drouths. Figure 3 shows the trees in the second seasons's growth.

Data have been kept upon a great many different points, but the only phases of any particular interest here are (1) the number of

potential fruiting parts developed and (2) the actual number of fruit buds formed. The number of fruiting parts was determined by counting the number of short branches, two inches or less in length, that had developed on the various trees, and the number of fruit buds by counting the number of blossom clusters that opened. These figures are given in Tables 39 and 40.

TABLE 39.—AVERAGE NUMBER OF POTENTIAL FRUITING PARTS DEVELOPED ON TREES IN FERTILIZER EXPERIMENT

Fertilizer	Medium	Year	
		1916	1917
N	Soil	53	64
	Sand	8	28
K	Soil	9	21
	Sand	12	17
P	Soil	8	19
	Sand	4	18
KN	Soil	31	62
	Sand	9	33
NP	Soil	49	52
	Sand	2	35
KP	Soil	8	15
	Sand	5	15
NKP	Soil	45	69
	Sand	6	22
Check	Soil	8	20
	Sand	6	30

NOTE: N—Sodium Nitrate. K—Potassium Sulphate. P—Acid Phosphate.

TABLE 40.—TOTAL NUMBER OF BLOSSOM BUDS PRODUCED ON TREES IN FERTILIZER EXPERIMENT

Fertilizer	Medium	No. Trees	Blossom Buds in		
			1916	1917	1918
N	Soil	2	7	45	22
	Sand	4	0	0	83
K	Soil	3	0	0	0
	Sand	4	0	0	0
P	Soil	3	0	0	0
	Sand	4	0	0	0
NK	Soil	4	11	29	287
	Sand	4	2	8	241
NP	Soil	4	8	8	117
	Sand	4	1	27	139
KP	Soil	3	0	0	0
	Sand	3	0	0	0
NKP	Soil*	4	37	124	306
	Sand	4	2	1	107
Check	Soil	4	0	0	2
	Sand	4	0	0	6

NOTE: N—Sodium Nitrate. K—Potassium Sulphate. P—Acid Phosphate.

*One tree in this lot had become girdled with a label wire and it alone produced 24 clusters in 1915.

From these two tables, it is very evident that the application of nitrogen has been a very decisive factor in both the formation of fruiting parts and the development of bloom buds. Apparently the mediums used needed little or no potassium or phosphorous in this connection, for these elements gave really no increase over the check when applied either singly or in combination. It is only where the nitrogen was added that any effect is noted, this effect being nearly as great in the loess soil plots as in the sand plots.

EFFECT OF THE TILLAGE SYSTEM UPON THE CONCENTRATION OF SAP IN YOUNG APPLE TREES

That the method of handling the soil and the kinds of plants used for intercropping a young orchard have considerable effect upon the subsequent bearing and behavior of apple trees is the conclusion that must be reached if weight is given the opinions of many growers. This phase of orchard management is now receiving considerable attention at the Missouri Experiment Station. Quite an extensive experiment was begun in 1911. Many of the trees, however, were not set until a year or two later. From time to time, it has also been necessary to replant because certain trees died. The present planting, therefore, consists of trees of different ages.

The problem, primarily, has been to make observations relative to the effect of various kinds of intercrops and cover crops and methods of soil treatment upon the vigor, size, earliness of bearing, and amount of fruit produced upon apple trees set in the loess soil on the University Fruit Farm. The planting consisted of several commercial varieties but it was so arranged that several trees of each variety were included in each of the tillage plots.

In arranging the cropping systems, an attempt was made to provide various degrees of cultivation ranging from clean cultivation with a leguminous cover crop, to a permanent timothy and bluegrass sod. In one plot, the ground was kept in a high state of cultivation up until June each year when a crop of cowpeas or soybeans was planted. A second plot has grown successive crops of corn, a third has been planted to red clover in alternate years, a fourth has produced successive crops of alfalfa and another has been seeded to permanent timothy sod. Thus, it will be observed that two plots are cultivated each year, one is plowed in alternate years and the others (one planted with a legume and one with a grass) receive no cultivation. (As a matter of fact, it has been necessary to plow and

then reseed the alfalfa plot two or three times on account of bluegrass.)

This project has by no means been carried to its conclusion, for the older trees are just now beginning to come into bearing. However, the following data concerning the freezing point depression of twig and leaf sap are of interest in connection with the present problem and for that reason are presented here.

TABLE 41.—EFFECT OF THE TILLAGE METHOD UPON DEPRESSION OF TWIG SAP OF APPLE TREES

Date	Variety	Depressions in the Various Plots				
		Timothy	Alfalfa	Clover	Corn	Cowpeas
Mar. 11, 1916	Jonathan	2.325	2.435	2.275	2.230	2.195
	Benoni	2.350	2.395	1.985	1.980	2.220
	Delicious	1.510	1.675	1.655	1.525	1.675
Apr. 10, 1917	Jonathan	1.760	1.695	1.655	1.765	1.685
Nov. 6, 1917*	King David	1.822	1.973	1.931	1.716	1.755
	Ben Davis	1.543	1.687	1.604	1.454	1.398
Mar. 22, 1918*	King David	1.439	1.517	1.482	1.339	1.215
	Rome	1.407	1.453	1.426	1.349	1.361

*These determinations were made by A. J. Winkler.

TABLE 42.—EFFECT OF THE TILLAGE METHOD UPON THE DEPRESSION OF LEAF SAP OF APPLE TREES

Date	Variety	Depressions in the Various Plots				
		Timothy	Alfalfa	Clover	Corn	Cowpeas
July 5, 1916	Jonathan	3.440	-----	2.790	3.540	3.640
	Benoni	3.160	-----	2.790	2.960	2.290
	Delicious	3.400	2.830	3.460	3.500	2.490
July 19, 1916	Jonathan	2.725	3.070	2.553	2.290	2.195
	Delicious	2.065	2.265	2.140	2.280	1.995
	Ben Davis	2.770	2.305	2.030	2.310	2.115
	King David	2.470	2.755	2.925	2.530	2.405
Aug. 4, 1916	Jonathan	2.285	2.520	2.200	2.465	2.570
	Delicious	2.180	2.245	2.485	2.310	2.305
	Ben Davis	2.260	2.505	2.385	2.220	2.180
	King David	2.430	2.455	2.565	2.500	2.875
Aug. 16, 1916	Jonathan	2.255	2.190	2.305	2.330	2.230
	Delicious	1.935	2.040	2.125	1.975	1.875
	Ben Davis	1.830	2.010	1.960	1.905	1.890
	King David	2.210	2.440	2.615	2.500	2.140

Table 41 shows very conclusively that the tillage method does materially affect the sap density of the twigs of apple trees. Contrary to what might have been expected, trees from the alfalfa plot show a greater depression of twig sap than trees from the timothy plot. As a general thing, there is not much difference between trees

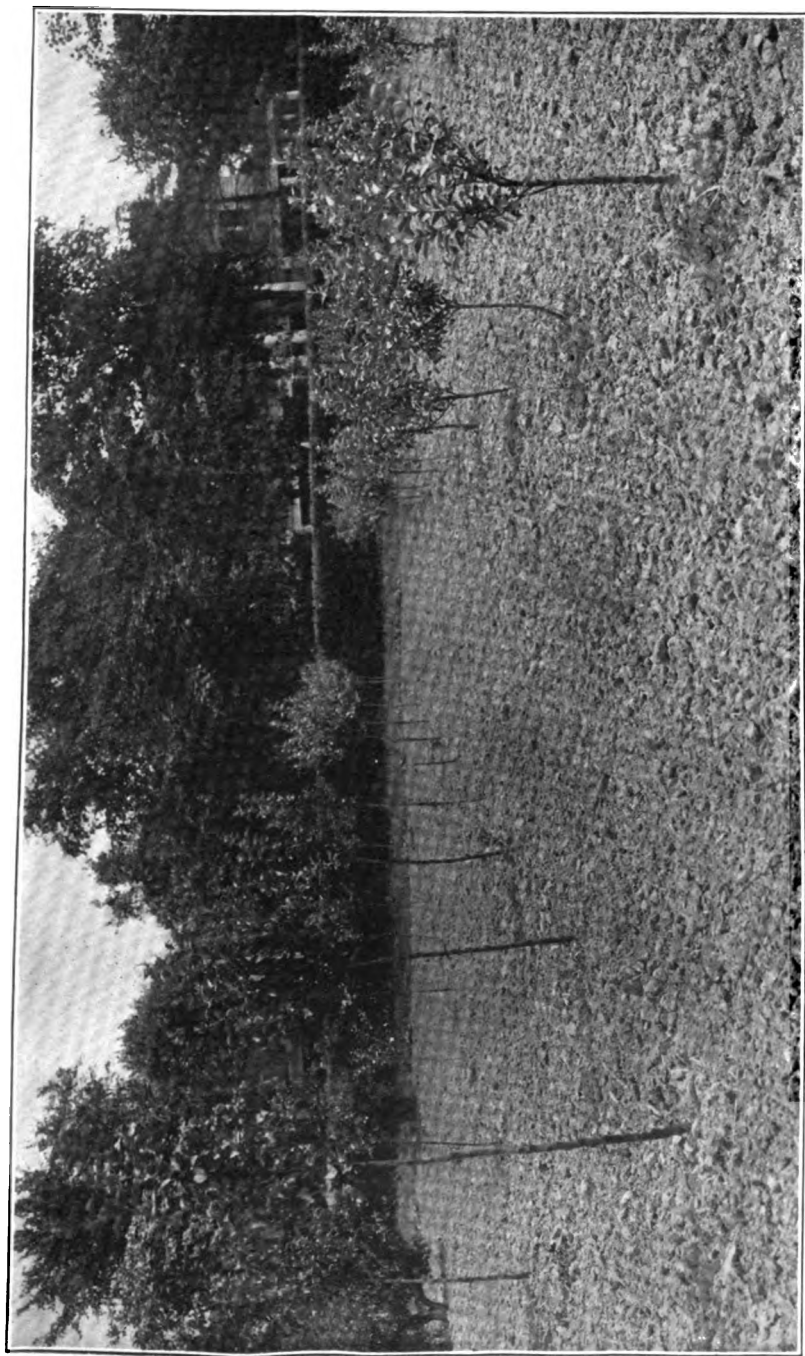


Fig. 4.—Delicious apple trees used in the pruning experiment. After the first season's growth



Fig. 5.—Jonathan apple tree showing effects of severe pruning. Note the large amount of watersprout growth. (Compare with Figure 6)



Fig 6.—Jonathan apple tree showing development of a large number of fruiting parts. (Compare with Figure 5, a tree of the same age but pruned more severely)

growing in clover sod and those intercropped with corn. These stand next to timothy in density and first above the trees in the cowpea plot. In the latter case, the concentration is least of all.

From these data, it would seem logical to conclude that the trees growing in timothy or alfalfa should be the ones to come into bearing earliest, a conclusion also supported by general observations. However, it must be stated that the trees in the more intensively cultivated areas are considerably larger at the present time and hence, in this way may be able to overcome the advantage that the other trees may now possess.

The figures representing the depression of leaf sap from trees growing in the various plots present such a wide range of variation that no safe conclusion can be drawn.

EFFECT OF THE PRUNING SYSTEM UPON THE FORMATION OF FRUITING PARTS

That pruning does have a very marked influence upon the fruiting habit of the tree has long been a matter of common observation. Dormant pruning in most instances has tended to promote wood growth and to decrease fruitfulness. Even different amounts of pruning done at the same time show considerable variation in their effects.

That the system of pruning may likewise be influential in causing the formation of fruit spurs is also nicely shown by the following figures compiled from data collected under another project. A pruning experiment was begun in 1914 upon 64 one-year-old Delicious apple trees with the object of determining the relative influence of different pruning systems (particularly high heads vs. low heads) upon the size, the character of growth, and the fruiting age of apple trees. The experiment is incomplete, yet the following table is interesting in connection with the present problem.

The trees were very uniform in size and were treated in exactly the same manner except one series was forced to form the head at a height of about two feet and the other at five to six feet. The accompanying photograph (Fig. 4) indicates the appearance of the trees after their first season's growth.

From the beginning it has been very noticeable that the low-headed trees make by far the greater amount of twig length growth and at the same time form a much larger number of branches. During the season of 1917, it was observed that the low-headed trees were forming a great many very short branches which made only a

limited growth, usually two inches or less, and then formed a terminal bud. Since this is the usual history of the formation of fruiting parts, it has been assumed that these were potential fruit spurs. While a large number of such branches probably would never develop into fruit spurs under normal conditions, yet it is likely that the relative number in the two sets of trees would be maintained. A record of the number of these short branches as well as the number of longer twigs was taken in the fall of 1917. The figures are given in Table 43.

TABLE 43.—AVERAGE NUMBER OF TWIGS AND FRUIT SPURS ON HIGH- AND LOW-HEADED APPLE TREES

	No. of Twigs	No. of Spurs
High-headed	35.5	14.9
Low-headed	62.8	34.1

From the foregoing it may be clearly seen that the system of pruning used has a very marked influence upon the number of potential fruiting parts formed in the early life of the tree, the low headed trees forming more than double the number of short branches or spurs found on the high-headed trees.

EFFECT OF ETHERIZATION UPON THE SAP DENSITY OF APPLE TREE FRUIT SPURS AND LEAVES

Etherization has proven to be a very effective stimulant upon the enzyme activity of detached parts of woody tissues. Howard⁶⁶ has made extensive experiments along this line. Since this treatment does have a marked effect upon the availability of the food supply, the thought has come that perhaps etherization of the entire tree at various seasons of the year might have some effect upon the amount of available food and thus influence the number of fruit buds formed for the following season. For the above reason the following experiment has been designed and carried out.

The effect upon the food supply was measured by the concentration of the sap from the treated as compared with the untreated trees. While they plainly do not justify any definite conclusions, yet the results are submitted below.

A number of Jonathan apple trees were available for this work. They were five or six years old, just at the point where fruitfulness normally begins. They were growing in the clay loam soil of the Experiment Station grounds.

Twelve trees were selected for etherization and a different one was etherized each month, beginning December, 1914, and continuing until November, 1915. For this exposure the trees were enclosed in a galvanized iron can and all joints tightly sealed. Ether was then introduced in sufficient quantity to have 0.5 cc. per liter of air space. A little injury to the leaves and new growth resulted from the May and June treatments. It was undoubtedly due to excessive temperatures inside the can at that time. Even tho an attempt was made to keep the temperature down by shading the can, yet it sometimes reached a fairly high point during the summer months. It is interesting to note that the trees treated in October began to show bud growth, especially near the ends of the main branches, early in November.

From time to time sap samples were secured from spurs and leaves on both etherized and unetherized trees. The results secured are given in Tables 44 and 45.

TABLE 44.—DEPRESSION OF SPUR SAP FROM ETHERIZED AND UNETHERIZED TREES

Date	Depression	
	Treated	Untreated
June 1, 1915.....	1.630	1.580
June 12, 1915	1.305	1.345

TABLE 45.—DEPRESSION OF LEAF SAP FROM ETHERIZED AND UNETHERIZED TREES

Date of Etherization	Depression on Date Given			
	July 16, 1915	June 17, 1916	June 30, 1916	July 17, 1916
December 12, 1914.....	1.580	2.790	1.760	1.710
January 12, 1915.....	1.530	2.280	1.750	1.750
February 20, 1915.....	1.560	2.280	1.750	1.750
March 12, 1915.....	1.600	2.040	2.210	1.910
April 12, 1915.....	1.630	1.840	2.180	1.810
May 13, 1915.....	1.590	1.730	2.030	2.030
June 12, 1916.....	1.610	2.200	1.680	1.640
July 13, 1915.....	1.660	2.430	1.680	1.730
August 10, 1915.....	.....	2.000	1.590	1.690
September 12, 1915.....	.....	1.760	1.720	1.740
October 14, 1915.....	.....	1.970	1.760	2.060
November 15, 1915.....	.....	2.280	1.730	1.910
Check	1.430	2.480	1.620	1.950

The small supply of leaves and spurs on the trees prevented a large number of determinations and then, too, the work had to be discontinued after the first series. The results probably do not

justify conclusions. It does seem, however, that ether has little effect upon the sap concentration of fruit spurs. The sap of the leaves apparently was affected by such treatment, but, as is seen by the later determinations, this effect does not carry over to the next year. The effect seems to be immediate. With the higher concentration of the leaf sap which comes in July because of etherization, the hypothesis might be advanced, that with a greater amount of food available a larger number of fruit buds might be formed. No supporting data, however, are furnished.

SUMMARY AND CONCLUSIONS

Missouri apple yields tend to rotate in three-year cycles, the sizes of the crops produced showing the following order: heavy, light, medium, heavy, etc.

A five-year study of the behavior of individual apple fruit spurs of six commercial varieties, as contrasted with previous opinions based upon casual observation of the entire tree or entire orchard, leads to the following conclusions:

Jonathan, Grimes and Winesap are able to develop a fairly high percentage of blooms each year, while Rome, York and Gano, produce an exceedingly high percentage of blooms one season and a very low one the next.

The varieties used show remarkable uniformity with respect to the percentage of the individual fruit spurs which alternate, that is, bloom only once in two years.

Jonathan and Winesap are able to develop blossoms in successive seasons on the same spur in a much greater proportion than the other varieties observed.

The soil in which a tree is growing has little effect, apparently, upon the performance of the individual spurs, with respect to alternation.

The fruitful year of certain alternating sorts may be changed by a removal of the blossoms thru either accident or design.

The age of the spur systems of the various varieties is practically the same, ranging usually from two to eight years, three to six or seven years being apparently the most effective fruiting age.

Sap from bearing spurs has a slightly higher concentration (lower freezing point) during a considerable portion of the year than sap from non-bearing spurs. The depression of the freezing point, however, gives no indication of the amount of starch which may be present.

A marked decrease in the sap concentration of both bearing and non-bearing spurs occurs in late June or early July.

Leaf sap from bearing and non-bearing spurs shows considerable variation in concentration.

The number of fruits on a spur affects the concentration of neither spur nor leaf sap.

Sugar and starch are present in slightly greater amounts in the bearing spur than in the non-bearing one. (Determinations made by chemical methods.)

Bearing spurs have a smaller total leaf area than non-bearing spurs, the difference being due to the number of leaves developed rather than the size of the individual leaves.

Experiments in girdling nursery apple trees gave the following results:

Girdling, regardless of the season, caused an increased concentration of sap in the parts above the girdle and a decreased concentration in the parts below. (Determinations made by freezing-point method.)

Girdling produced its most marked effect in the parts nearest the girdle, the effect being lessened as the distance from the girdle increased.

Fertilizer experiments with dwarf Rome apple trees planted in boxes of sand or soil showed that effects upon (1) the size of the tree, (2) the development of its fruiting wood, and (3) the production of blossoms, could be attributed only to the use of nitrogen. Potash and phosphorus applied either singly or in combinations had no apparent effects.

Tillage experiments showed that trees growing in a permanent sod of either a grass or a legume had a higher concentration of twig sap than trees growing in plots planted with either annual or biennial cultivated crops.

Trees headed at five or six feet did not produce so many short branches—potential fruiting wood—during the first three years in the orchard, as trees headed at two feet.

Etherization of young Jonathan apple trees had little effect upon the concentration of either twig or leaf sap, and the small differences observed seemed to be only temporary.

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AN INVESTIGATION IN TRANSPLANTING

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SUMMARY

A review of the existing literature, bearing upon the season at which fruit trees should be transplanted, shows that a majority of the authors recommend spring planting.

A classification of these expressed opinions based upon the climatic condition at the source of each, reveals the fact that for the most part those who recommend spring planting base their opinion upon experience in sections where winter conditions are trying, and those who recommend fall planting base their advice upon experience in the milder fruit-growing sections.

Those who express a preference for fall planting, emphasize the desirability of planting in very early autumn, for the alleged reason that it gives time for the roots of the trees to become better established before cold weather approaches. Experience at the Missouri Experiment Station shows that this does not hold true under Missouri conditions.

At the Missouri Experiment Station fall planting hardy fruit trees and most hardy deciduous trees and shrubs has given better results than spring planting.

Late fall planting has given better results than early fall planting.

Late spring planting has given as good results as early spring planting, providing the trees are kept dormant until they are planted.

Trees "heeled in" for planting may be held dormant until late spring, sometimes until early June, by lifting them out of the trench, turning them over, and again heeling them in in the same trench, as often as their buds show indication of starting.

Sour cherries usually suffer a mortality of one-third to one-half of the number of trees when planted in spring, but suffer no appreciable mortality when planted in late fall.

Peaches and most species which are subject to winter injury under Missouri conditions succeed best when planted in the spring.

Coniferous evergreens succeed best if transplanted just as their new growth is starting in the late spring. If the soil is moist and the weather is humid they may be transplanted in early autumn with satisfactory results.

Certain species of trees transplant best under special conditions mentioned in this bulletin.

Apple trees planted in the fall usually begin new root formation about the first of January, from the sides of the lower main roots, after the surface soil has frozen. Early fall-planted trees have begun root growth no earlier than late fall-planted trees. New root growth apparently proceeds slowly thruout the winter, below the frost line.

Apple trees planted in early fall dry out more during fall and winter than do those planted in late fall. The reason, apparently, is that their parts are less thoroly ripened or not fully at rest at the time of early planting. This date is followed by a period of high atmospheric temperatures and often by dry weather.

There is an obvious accumulation of soil warmth about the roots in early winter, beneath the frozen crust. New root formation may be stimulated by this "bottom heat" which passes upward in early winter. New root growth begins on the lower roots of fall-set trees and on the roots nearest the surface in the case of spring-set trees. New root growth apparently does not begin essentially earlier on early spring-planted trees than on those set later. In both cases new root growth starts with the advent of the leaves, or even later.

Fall-planted trees, mulched during the winter, have made slightly poorer growth than those not mulched. The soil about the mulched trees dries and warms more slowly, even where the mulch is removed in early spring.

Young apple trees having their branches pruned back in autumn make better growth the following season than do trees pruned back in spring. This holds true whether or not the trees are transplanted. Branches pruned back evaporate more water thru the wounds than do similar branches which are not pruned, for the first few days only. After the first few days the pruned branches lose less water thruout the winter than do those which are not pruned.

The wound made in pruning back a twig, or a slight wound anywhere on a twig, stimulates greater growth of adjacent buds. A wound made just above a bud stimulates greater growth than a similar wound made below or at the side of a bud. Wounds made

in autumn stimulate greater growth the following season than do similar wounds made in the spring.

In transplanting fruit trees under Missouri conditions the roots, generally, should be set no deeper than they stood in the nursery. This is especially true if the trees are set in the spring, at which time the soil is slow in warming to the depth of the lower roots.

The tendency of trees in the orchards of this region to lean toward the northeast may be overcome in part by proper orientation of the trees at the time of transplanting, as explained in the text of the bulletin.

In setting fruit trees the soil should be pressed firmly about the roots to avoid drying out; the main roots should be set in their normal position without being bent or twisted. Digging large holes for the trees or shattering the subsoil is not necessary, except under certain conditions explained in the text.

The small, fibrous roots of transplanted fruit trees usually die, due to drying out or bending in setting, unless they can be dug and reset immediately with a mass of soil. The dead, fibrous roots should be pruned away at the time of transplanting, since they are an encumbrance and prevent pressing the soil into close contact with the larger essential roots.

The tops of young fruit trees should be pruned back at the time of transplanting, the degree of pruning differing with the character and habit of growth of the species.

The roots of fruit trees should not be allowed to freeze in handling. Tests show that while the tops of the trees may endure severe freezing without injury, the roots may be injured even by a few degrees of frost.

Garden vegetables such as cabbage, tomatoes, etc., will endure lower temperatures and greater extremes of drouth without injury, after transplanting, if grown more slowly in the forcing bed than is customary. Such vegetables grown in a seed bed of sandy soil, low in plant food, watered sparingly and ventilated freely have large fibrous root systems, short, stocky, firm, woody stems, and a concentrated sap of low freezing point. Vegetables grown in a seed bed of rich soil, highly manured, abundantly watered and in a high temperature with little ventilation, have scanty root systems, long stems, luxuriant leaves, succulence and a less concentrated sap of higher freezing point.

Part I.—The Development of Fruit Trees as Influenced by Season of Transplanting

INTRODUCTION

The season of transplanting, as a factor affecting the subsequent development of fruit trees, appears to have been the object of comparatively little experimental investigation. It is the usual custom of most fruit growers to transplant their trees in the spring. Possibly this custom may be the outgrowth of the opinion among early agriculturists that "the spring is Nature's time to plant." While spring transplanting is most largely practiced, practical experience has shown that most deciduous trees may be successfully planted at almost any time during their dormant period when soil and climatic conditions are at all favorable.

There is some conflict of opinion as to the most favorable season for transplanting fruit trees. Reference to the leading manuals on this subject shows that in both Europe and America a minority prefer fall planting. Some express no preference between fall and spring. Those who prefer fall planting usually emphasize the desirability of planting in very early autumn for the alleged reason that it gives time for the roots of the tree to become better established before cold weather approaches.

A careful classification of these expressed opinions, based upon the climatic conditions at the source of each, reveals a very interesting fact which apparently has not been adequately considered. It is found that those who recommend spring planting base their opinions upon experience in severer climates, while those who recommend fall planting base their advice upon experience in the milder fruit-growing sections. Careful consideration of the foregoing fact suggests that spring planting may perhaps be preferable toward the north and fall planting toward the south.

The abundant experience of practical fruit growers may seem to be an adequate basis upon which to decide this question for a given district. However, emphatic opinions differ, even among fruit growers of the same neighborhood. In view of these differences of opinion among practical growers, and in view of the fact that definite experimental data seem to be inadequate, the writer

has been unable to satisfy the question as to the best season for transplanting for Missouri orchardists. For this reason, observations of the behavior of fall- and spring-planted trees were begun at the Missouri Experiment Station about twenty years ago. Frequent visits were also made to large commercial orchards which contained both fall- and spring-planted trees. These observations revealed evidences that fall planting was to be preferred. Consequently, definite experiments were begun in 1908 with a view to recording accurately the results of fall and spring planting, and, if possible, to determine the reason for any difference in the behavior of the trees. These experiments have yielded results that should prove of value to Missouri orchardists.

Additional questions in connection with transplanting, such as the depth to plant, orientation of the tree, mulching, shaping the tree at transplanting, etc., have arisen and have been given attention.

In view of these results it is of interest to review and to attempt to harmonize existing data and opinions in their relation to results secured at the Missouri Experiment Station.

A BRIEF REVIEW OF LITERATURE REGARDING THE SEASON OF TRANSPLANTING

Lindley^{33*} in "Horticulture" states that fruit trees may be transplanted successfully at almost any time during their dormant period. After a full discussion of the matter he finally concludes that "the earliest time at which planting can be effected after the leaves fall in autumn is, upon the whole, the best." He states that this allows the wounds a longer time to heal, thus resulting in less injury to the plant.

Downing¹⁸ in "Fruits and Fruit Trees of America" concludes that "autumn planting is greatly to be preferred in all mild climates, on dry soils; and even for very hardy trees like the apple in colder climates; as the fixed position in the soil which the trees planted then get by the autumnal and spring rains, give them the advantage at the next season of growth over newly planted trees."

Bailey¹ in "The Principles of Fruit Growing" writes: "Fall planting is generally preferable to spring planting on thoroly drained and settled lands, particularly for hardy tree fruits like apples, pears and plums, and if the ground is in good condition and the stock well matured, peaches may be sometimes set in October, even in northern states with success." He states further that it is usually better to buy trees in the fall; "these trees must be kept until plant-

stibliography.

*The number, following the author's name, indicates reference to be found in the

ing time, and it is about as cheap and fully as safe to plant them directly in the field as to heel them in until spring."

Thomas⁴⁸ in "The American Fruit Culturist" advises against removing the tree from the nursery too early, against planting when the soil conditions are unfavorable, and to prevent injury to heeled-in trees during winter. He concludes "it is a matter of small consequence at which season the trees are planted out, provided the work is well done."

Engler⁵⁰ in a paper on the root development of trees gives the following general rule: "In regions with well marked spring and fall rains, spring is the best time; in regions with dry summers and fall rains, fall planting is the time of the beginning of renewed activity of the roots which will vary with the species and locality between the end of September and the middle of October, and should be ascertained locally."

Brackett⁹ expresses the belief in Farmers' Bulletin 11, that the season of transplanting is governed somewhat by latitude, and mentions as an objection to fall planting that "the roots of a tree do not take hold of the ground sufficiently to supply moisture to maintain a healthy, active circulation of the sap, which is required to prevent shriveling of the branches during winter's extreme cold and exhaustive evaporation from drying winds."

The six writers cited above are representative of widely separated sections of Europe and America. Three definitely committed themselves in favor of autumn transplanting. The other three express no decided preference between fall and spring. They mention, however, precautions necessary to avoid injury, provided planting is done in the fall. Each discusses the question broadly enough to indicate that the time for transplanting may vary with conditions in a particular section.

In order to throw further light upon the transplanting season which is perhaps most favorable in different districts of the United States it will be of interest to classify representative writings in accordance with the different fruit-growing regions of this country.

In making this classification the fact should be kept in mind that undoubtedly each author has considered the problem more widely than with reference to the locality in which he wrote. In a general way, however, this classification seems helpful in determining what are the conditions which favor or oppose transplanting under a given set of conditions.

NORTHEASTERN DIVISION OF THE UNITED STATES

Sears⁴⁶ of Massachusetts states that fall planting is objectionable chiefly for the reason that the nurserymen may have to strip the leaves from the trees in order to take them from the nursery early enough for transplanting at this season. He expresses preference for transplanting fruit trees just as early in spring as the soil is in good condition to work. Jarvis⁵⁰ of Connecticut states that if soil and weather conditions are favorable after the stock arrives the trees may be safely and profitably planted in the fall. His entire discussion indicates apparently a slight preference for fall planting. Gourley of New Hampshire reports very favorable results from fall planting of apple trees. Wilkinson⁵³ of New York is quoted as follows: "If stock arrives in time [in the fall] it may be safely and profitably placed where they are to remain permanently. If conditions in fall are not right, spring planting is undoubtedly the safer course."

NORTH-CENTRAL DIVISION OF THE UNITED STATES

White⁵⁰ of Michigan believes that in general the best season to plant depends upon the convenience of the planter but states the precaution: "If in any doubt as to the time to plant, leave it until spring." Erwin⁵¹ of Iowa advises spring planting for the upper Mississippi valley and says that "trees which have been disturbed in the fall by transplanting are more subject to root killing the following winter. The work should be done in spring so that the roots may have time to become established before the hot dry weather of August." Green⁵⁷ of Minnesota likewise favors spring planting as a rule for the extreme north. He states further, however, that the very hardy fruit trees may be set in autumn provided they are afterward laid on the ground at the approach of winter and covered with earth and a little mulch to protect them from severe winter temperatures.

CENTRAL AND SOUTHERN STATES

Whitten⁵¹ of Missouri advises fall planting for all hardy, deciduous species, and spring planting for tender species. He observes that root growth will progress below the frost line during the winter in the case of fall-planted trees, but that the root growth of spring-planted trees is slow and uncertain and that the trees frequently come out in leaf before their new root growth becomes

established. Chandler²¹ of Missouri says: "In most of Missouri it is not best to plant peach trees in the fall on account of the danger from severe weather and dry winters, tho in a very favorable year the fall-planted trees will make better growth the first summer. In the extreme south if the ground is in good, moist condition very late in the fall or early in winter, it would be desirable to plant the trees then and a good mulch of some kind would be of great advantage."

Berchmans⁸ of Georgia advises that where the soil is naturally dry and warm all hardy and deciduous trees should be planted as early in the fall as the growth ceases and the usual growth is well hardened off. He states further that in sections where the climate is mild, trees are inactive in their parts above ground during winter but remain active below ground in the formation of new roots.

SEMI-ARID WESTERN STATES

Paddock⁴¹ of Colorado recommends spring planting only, for the semi-arid fruit sections of the west. Shinn⁴⁸ of Idaho regards spring planting as safer for Idaho orchardists because of a drying out of fall-planted trees during their dry autumn and winter. He advises digging the trees in the fall and heeling them in, in order to give opportunity for callusing of the injured roots before spring, which he regards as "one of the main benefits of fall planting." Garcia²² of New Mexico, for similar reasons advises spring planting for New Mexico orchardists.

PACIFIC COAST STATES

Wickson⁵² of California emphasizes two factors which should cover the season for transplanting fruit trees—the dormancy of the tree and the proper condition of the soil. He states that these factors are more apt to coincide in most parts of California about the first of January. He found that trees transplanted early had their wounds callused over and new rootlets considerably advanced before the buds begin to swell. Lanham⁵⁴ of Washington reports observations upon one thousand acres of apple trees planted from December 1, 1910, to April 1, 1911, and summarizes with the following comment: "The first planting made at least twice the growth of those set out last with a gradual gradation between."

Of horticulturists quoted from the northeastern states, three out of four prefer fall planting. The objection to fall planting raised by the fourth is that the trees may have to be lifted from the nursery

before they are fully matured in order that the orchardist may be able to secure them before the ground freezes. This objection, therefore, applies to inconvenience of getting the trees to the orchard on time and does not necessarily indicate whether or not fall planting might be preferable if thoroly ripened trees could be secured sufficiently early. It should be observed in this connection that the northeastern section has a maritime climate in direct contrast to the dry winter climate of the north central states, the interior plains or the Rocky Mountain district.

Spring planting is generally recommended in the extreme north central states as well as prairie and Rocky Mountain states where the winters are dry and where the trees are subject to extreme winter desiccation.

It is apparent that in the central and southern states where rainfall is adequate and where the winters are mild, fall planting is preferred by the writers quoted.

In the Pacific Coast states where most of the rainfall occurs during their mild winter, December and January is recommended as the best planting season.

The advice summarized above no doubt represents a safe guide for general practice in the various districts of the United States. It is based upon the observation and wide experience of men who have given the general subject careful attention and who may be depended upon to represent an accurate judgment as to sound experience in their district.

A number of horticulturists have submitted definite data concerning the relative behavior of trees planted at different seasons. A consideration of these data is of interest. Koopman²² reports the results of extensive experiments conducted at Potsdam giving the following summary:

- I. Fall planting gave better results than spring planting in eighteen cases.
- II. Fall planting gave the same results as spring planting in five cases.
- III. Fall planting gave inferior results to spring planting in thirteen cases.
- IV. Winter planting gave inferior results to fall planting in ten cases out of eleven.
- V. Winter planting gave inferior results to spring planting in ten cases out of eleven.
- VI. Early spring planting gave better results than late spring planting in all cases.

In Koopman's experiments the best results were in some cases secured with fall-planted trees and sometimes with spring-planted trees. After careful study and discussion of these results he recommends transplanting in the fall immediately after the leaves are shed or in the spring at the time the buds first begin to swell. He found either of these periods more favorable than very late fall or late spring.

Bedford and Pickering² in reports of the Woburn Experimental Fruit Farm, give the results of experiments dealing with the season of transplanting apple trees in England. They found that apple trees planted November 28, 1894, were, after one year's growth, decidedly less vigorous than the winter- or spring-planted trees. They state in this Report (2-1897) that "this would indicate that the generally received opinion as to the superiority of autumn as to the best time for planting is erroneous, but that the experiment must be repeated before drawing a positive conclusion." In a later experiment, 1905, five different plantings were made—one in early autumn, one in late autumn, one in winter, one in early spring and another in late spring. When the trees of these plantings were four years old they were carefully lifted and their weights compared with their weights when planted. The results showed that the percentage increased weight of the trees planted October 30 was nearly twice as great as that of those planted April 18, and was 75 per cent greater than the increase of the trees set in late fall or December 3. While their conclusions were in favor of early fall planting, they further state that, "unfortunately, it is rarely possible for growers to obtain their trees early enough to secure the advantages which very early autumn planting offers, unless the trees have been raised on the farm itself. Nevertheless, we should always advise planting as early as possible for the soil is more likely to be in a suitable condition than later on and the trees are less likely to be exposed to drying winds."

It was also found by Bedford and Pickering that apple, pear, plum and quince trees planted in autumn formed new roots in a majority of cases before January 15.

Card¹⁰ in bulletin 56 of the Nebraska experiment station gives the results of an experiment in co-operation with the Missouri Botanical Garden in fall and spring planting of apple and peach trees. His results lead to the conclusion that fall planting was preferable for the vicinity of St. Louis, but that upon the plains of Nebraska spring planting was to be preferred, due to winter desic-

cation of fall-planted trees. He also determined that fall-planted trees can make growth of roots in the fall after planting and in early spring before growth of their tops begins.

Clement¹⁵ of Vineland, Ontario, found that spring planting of cherry trees resulted in the death of a large proportion of the trees, while fall planting gave favorable results. Clement also made fall and spring plantings of pear and plum trees for three successive years. In each case the fall-planted trees made the better growth.

The foregoing review of experimental evidence indicates that the best season for transplanting probably depends upon environmental conditions of the tree in the district where it is grown.

INVESTIGATIONS IN TRANSPLANTING AT THE MISSOURI EXPERIMENT STATION

In 1907, an experiment was begun at the Missouri Experiment Station with the object of determining whether fall or spring was the more favorable season for transplanting fruit trees, under Missouri conditions. Preliminary observations had been going on for more than a decade previous to 1907. In developing the horticultural grounds some fruit trees and deciduous shade trees had been planted in the fall and others in the spring, of nearly every year, since 1895. These trees were planted for other purposes than to determine the best season for transplanting. They afforded opportunity, however, for general observations upon this problem. Numerous large orchard plantings were then being made in the state. Trees were being set both in fall and spring. Many of these orchards were visited where fall and spring planting on a large scale could be observed.

Careful observation indicated that autumn was the more favorable season for transplanting hardy, deciduous trees in Missouri. These observations, however, were not sufficiently convincing. Often it was not possible to determine positively to what extent any difference in the growth of the trees might be due to the season of transplanting or to other causes. The fall- and spring-planted trees may have been grown in different nursery blocks; they may have been set and pruned by different workmen; soil conditions might vary; they may have been exposed to different influences during shipment; an autumn-set block might be given tillage or planted to a companion crop of vegetables just as the spring planting was going out; these and other causes arose to complicate the problem.

In order to secure more reliable data it was planned to grow trees in the Experiment Station nursery and give them uniform treatment, in every respect other than season of transplanting in the orchard.

In the spring of 1907, grafts of Jonathan apple were set in the nursery. Care was taken to select scions and roots of similar character. Several thousand trees were propagated from which to select for fall and spring planting in the orchard. By November, 1908, these trees were well matured, nicely branched, typical two-year-olds.

Forty trees were selected for the fall and spring transplanting experiment. They were selected in pairs, in order that each autumn-set tree might duplicate as nearly as possible a similar tree set in spring.

On November 12, 1908, twenty of these trees were transplanted to their permanent position. The site selected was adjacent to the nursery in order that the two sets of trees might winter under similar conditions except as to the season of transplanting. At the time of transplanting the trees in the fall their side branches were cut back in the usual manner, and on the same day the twenty duplicate trees remaining in the nursery for spring planting were similarly pruned.

On April 22, 1909, the twenty trees reserved for spring planting were set adjacent to those which had been set in November. The trees received good cultivation and similar treatment during the summer of 1909. A portion of them were dug up from time to time in order to observe the root development and other factors to be referred to later in this discussion.

At the close of their season's growth in 1909, careful measurement was made to determine the comparative length growth of new branches and trunk diameter of the fall- and spring-set trees. The results are shown in Table 1.

TABLE 1.—COMPARATIVE GROWTH IN 1909 OF JONATHAN APPLE TREES SET IN NOVEMBER, 1908, AND APRIL, 1909

10 trees set in fall, Nov. 12, '08			10 trees set in spring, Apr. 22, '09		
Tree No.	Length growth, inches	Caliper inches	Tree No.	Length growth, inches	Caliper inches
1	247.0	12/16	1	170.7	11/16
2	377.5	12/16	2	185.0	12/16
3	324.0	12/16	3	99.5	10/16
4	16.0	15/16	4	42.0	10/16
5	260.0	12/16	5	133.0	9/16
6	411.5	13/16	6	105.0	9/16
7	195.0	13/16	7	173.5	15/16
8	210.0	13/16	8	190.5	11/16
9	104.0	12/16	9	21.0	10/16
10	294.0	15/16	10	124.0	12/16
Average	243.8	12 1/2/16	Average	144.8	11 1/2/16

It will be seen from Table 1 that the fall-transplanted trees made almost double the total length growth of new branches that was made by the trees planted in spring. The average total length growth of the former was a little over twenty feet, and of the latter a little over ten feet. Only one spring-planted tree (No. 4) made more growth than the comparable one (No. 4) planted in the fall.

The caliper of the trees, six inches from the ground, was thirteen-sixteenths inches for the fall-set trees and eleven-sixteenths inches for the spring-set trees. This greater diameter of trunk is of especial interest, especially for Missouri conditions. A "stocky" tree stands up straighter in this section where young trees tend to lean toward the northeast as a result of southwest winds in summer, and alternate thawing and freezing of their cells on the sunny side of the tree in winter.

On the spring-set trees the principal length growth was confined to twigs near the outer tips of the main limbs. Few of the buds near the base of the limbs made any growth and these were mainly short "rosettes." On the fall-planted trees the buds toward the base of the limbs started more freely and made length growth fairly comparable with that made at the periphery of the trees. Since length growth from the outer tips of the main limbs was fairly comparable in both fall- and spring-planted trees the former had but little wider spread than the latter. Casual observation failed to indicate the actual difference in growth which was revealed by measurement of all the branches. Possibly this may explain why fall planting has not been more emphasized by orchardists who have had extensive experience in both fall and spring planting in this section. The relative number of new twigs produced was not recorded as its possible significance was not fully appreciated until the trees had been pruned in winter following their first year's growth.

The subsequent growth during 1910 and 1911 of the same Jonathan trees is recorded in Tables 2 and 3. In these tables also are inserted columns which show the number of new branches which made a growth of more than one inch during the respective seasons. These tables show the autumn-set trees continued to make greater average growth than the spring-set trees, altho the difference was less marked as the trees became better established. The freer branching habit of the fall-set trees is also worthy of note. As will be subsequently observed, this bears a relation to the earlier and more abundant setting of fruit spurs on the fall-planted trees as they approached fruiting age.

TABLE 2.—COMPARATIVE GROWTH IN 1910 OF JONATHAN APPLE TREES SET IN NOVEMBER, 1908, AND APRIL, 1909

10 trees set in autumn, Nov. 12, '08				10 trees set in spring Apr. 22, '09			
Tree No.	Length growth, feet	No. of branches	Caliper inches	Tree No.	Length growth, feet	No. of branches	Caliper inches
1	84.1	52	1 4/16	1.....	80.7	50	1 4/16
2	106.2	63	1 5/16	2.....	73.4	50	1 5/16
3	99.6	58	1 5/16	3.....	56.5	42	1 2/16
4	40.3	42	1 1/16	4.....	42.6	40	1
5	78.7	49	1 4/16	5.....	69.1	56	1 3/16
6	99.8	60	1 5/16	6.....	58.0	45	1 4/16
7	102.3	52	1 3/16	7.....	95.1	80	1 7/16
8	109.0	69	1 6/16	8.....	54.3	45	1 5/16
9	60.0	53	1 4/16	9.....	46.1	36	1 3/16
10	112.4	69	1 8/16	10.....	58.1	37	1 4/16
Average	89.24	56.7	1 9/32	Average	63.6	48.1	1 8/32

TABLE 3.—COMPARATIVE GROWTH IN 1911 OF JONATHAN APPLE TREES SET IN NOVEMBER, 1908, AND APRIL, 1909

10 trees set in fall, Nov. 12, '08				10 trees set in spring, Apr. 22, '09			
Tree No.	Length growth, feet	No. of branches	Caliper inches	Tree No.	Length growth, feet	No. of branches	Caliper inches
1	85.20	104	1 21/32	1.....	138.04	128	1 9/32
2	114.87	136	1 18/32	2.....	108.95	108	1 9/32
3	107.37	104	1 19/32	3.....	102.45	72	1 6/32
4	83.62	77	1 12/32	4.....	30.62	65	1 3/32
5	77.39	127	1 19/32	5.....	47.79	74	1 3/32
6	119.29	131	1 16/32	6.....	72.56	79	1 14/32
7	128.79	142	1 16/32	7.....	121.35	165	1 22/32
8	98.41	151	1 16/32	8.....	80.08	77	1 12/32
9	93.41	115	1 14/32	9.....	52.79	75	1 5/32
10	107.45	155	1 28/32	10.....	90.77	114	1 16/32
Average	101.58	124.2	1.55	Average	84.54	95.7	1.31

A summary of the average length and diameter growth of the fall- and spring-set Jonathan trees, for the first three years, appears in Table 4.

TABLE 4.—COMPARISON OF AVERAGE LENGTH AND DIAMETER GROWTH OF AUTUMN- AND SPRING-SET JONATHAN APPLE TREES DURING 1909, 1910 AND 1911

Autumn planted, Nov. 12, '08			Spring planted, Apr. 22, '09		
Season	Length growth, feet	Diameter growth, inches	Season	growth, feet	Diameter growth, inches
1909	20.3	0.81	1909.....	10.3	0.68
1910	89.24	1.28	1910.....	63.63	1.25
1911	101.58	1.56	1911.....	84.54	1.31

After their third year's growth in the orchard both the fall- and the spring-set trees had become so large that it did not seem feasible or desirable to attempt to keep further record of their entire twig growth. The trees were pruned to open, spreading heads each winter to admit light and encourage fruit spur formation. The more vigorous growth of the fall-set trees resulted in their producing a somewhat larger quantity of surplus growth which was removed in pruning. As a result there was no very visible difference in the size of the fall- and spring-set trees after the third year.

As previously noted, the fall-set trees made a larger number of secondary twigs in the body of the tree. They earlier began the differentiation of definite fruit spurs. In 1915, the fall-set trees produced their first crop of fruit, consisting of one peck of finely developed apples, distributed over six of the ten trees. One of the spring-set trees produced three apples. In 1916, the fall-set trees produced one and one-half bushels of fruit and the spring-set trees one peck of fruit. In 1917, a light crop was produced, about equally distributed on fall- and spring-set trees. In July, 1918, both sets of trees are carrying a good crop which appears to be about equally distributed. While the fall-set trees showed a tendency to form fruit spurs earlier and set more fruit the first two fruiting seasons, it is not apparent that their gain in fruitfulness is significant once the trees reach a fully established bearing habit.

In the fall of 1913, and spring of 1914, additional plantings were made. Additional types and varieties were included in order to determine whether the different sorts gave similar response with reference to the season of transplanting. This test also included one-year-old as well as two-year-old trees in order to determine whether the smaller trees, planted in autumn, would endure the winter as well as the larger trees.

A comparison of transplanting in early autumn as well as in late autumn and early spring and late spring was also made in order to determine when root growth begins after each planting. The summarized results appear in Tables 5 to 22.

Reference to Tables 5 and 6 shows that the average diameter of the fall-planted trees, at the end of the growing season, was $50/64$ inches, as compared with $40/64$ inches for the trees set in spring, which represents an annual increase in diameter for the season of $22/64$ inches and $10/64$ inches, respectively.

Further examination of these data shows that the fall-set trees made approximately two-thirds of their annual diameter growth

previous to August 14, while the spring-set trees made approximately two-thirds of their annual diameter increment after August 14. Measurements taken August 14 show that the fall-planted trees had increased 12/64 inches in diameter and the spring-set trees only 3/64 inches in diameter on the same date. The average diameter increase during the remainder of the season was 10/64 and 7/64, respectively, for the fall- and spring-set trees.

TABLE 5.—GROWTH DURING SUMMER OF 1914 OF TRANSPARENT APPLE TREES
Planted November 8, 1913

No. of trees	Diameter when set, inches	Diameter Aug. 14, 1914, inches	Diameter, Nov. 20, 1914, inches	Amount of twig growth, inches
1*	32/64	44/64	32/64	231
2	28/64	38/64	45/64	312
3*	20/64	46/64	49/64	208.5
4	28/64	44/64	52/64	251
5*	32/64	45/64	54/64	150
6	26/64	45/64	55/64	406
7*	28/64	43/64	48/64	222
8	32/64	48/64	55/64	353.5
9*	32/64	49/64	50/64	295
10	32/64	37/64	41/64	166
11*	28/64	35/64	37/64	136.5
12	32/64	33/64	46/64	116
13*	24/64	40/64	41/64	133
14	32/64	31/64	44/64	197
15*	24/64	32/64	37/64	126
16	24/64	30/64	44/64	136
17*	28/64	34/64	39/64	101.5
18	28/64	33/64	37/64	120
19	26/64	34/64	49/64	173
Total	540/64	741/64	855/64	3834
Average	28/64	39/64	45/64	201.8

*Mulched at time of planting.

TABLE 6.—GROWTH DURING SUMMER OF 1914 OF TRANSPARENT APPLE TREES
Planted April 27, 1914

No. of trees	Diameter when set, inches	Diameter Aug. 14, 1914, inches	Diameter, Nov. 20, 1914, inches	Amount of twig growth, inches
1	32/64	34/64	39/64	94
2	20/64	25/64	38/64	131
3	24/64	36/64	44/64	85
4	36/64	37/64	49/64	170
5	40/64	38/64	44/64	132
6	20/64	28/64	32/64	141
7	24/64	27/64	44/64	95
8	28/64	31/64	35/64	120
9	28/64	30/64	35/64	132
10	36/64	37/64	50/64	39
11	32/64	38/64	43/64	78
12	40/64	37/64	40/64	70
13*	-----	-----	-----	-----
14*	-----	-----	-----	-----
15	24/64	32/64	40/64	138
Total	384/64	430/64	533/64	1425
Average	30/64	32/64	40/64	104.2

*Trees died during the summer.

The slower growth of spring-set trees during the early part of the season has been observed in all the plantings, generally, where fall and spring planting has been compared at this Station. The spring-set trees put out their leaves and grow slowly, early in the season, as if leaf growth were waiting for the retarded root growth to catch up. If the early season is dry, any mortality of the trees usually takes place during this period, before their roots become well established. The fall-planted trees, on the contrary, make more rapid and continuous growth early in the season than they do later. This is no doubt due to the fact that their root growth is established early enough to support continuous rapid growth after they leaf out. The two spring-set trees which died, numbers 13 and 14 in Table 6, came out in leaf, persisted for a time with little added growth, and finally died as root growth failed to become established in time to support their tops.

The average total length growth of autumn- and spring-set trees, Tables 5 and 6, was 207.8 and 104.2 inches, respectively. These Transparent trees, like the Jonathan trees previously discussed, showed twice as much length growth of twigs on fall-set trees as was made by those set in spring. Their increase in diameter growth was more marked in favor of fall planting.

TABLE 7.—GROWTH DURING THE SUMMER OF 1914 OF AUTUMN PLANTED GRIMES APPLE TREES
Twelve trees planted in autumn, Dec. 6, 1913

No. of trees	Diameter when set, inches	Diameter Aug. 14, 1914, inches	Diameter, Nov. 20, 1914, inches	Amount of twig growth, inches
1*	20/64	24/64	24/64	52
2	16/64	25/64	24/64	74
3*	28/64	38/64	44/64	90
4	28/64	34/64	55/64	149
5*	20/64	38/64	48/64	333
6	32/64	37/64	44/64	191
7*	24/64	30/64	34/64	187
8	20/64	27/64	32/64	171
9*	20/64	37/64	48/64	161
10	20/64	30/64	40/64	111
11*	32/64	37/64	42/64	119
12	28/64	34/64	35/64	110
Total	288/64	396/64	470/64	1748
Average	24/64	33/64	39/64	145.7

*Mulched at time of planting.

TABLE 8.—GROWTH DURING THE SUMMER OF 1914 OF SPRING PLANTED GRIMES APPLE TREES

Transplanted April 8, 1914

No. of trees	Diameter when set, inches	Diameter Aug. 14, 1914, inches	Diameter, Nov. 20, 1914, inches	Amount of twig growth, inches
1* _____	_____	_____	_____	_____
2* _____	_____	_____	_____	_____
3* _____	_____	_____	_____	_____
4 _____	28/64	31/64	31/64	52
5 _____	28/64	30/64	34/64	22
6 _____	32/64	34/64	38/64	203
7 _____	24/64	28/64	34/64	144
8 _____	24/64	30/64	34/64	152
9 _____	12/64	28/64	28/64	29
10 _____	24/64	32/64	41/64	234
11 _____	24/64	31/64	33/64	33
Total _____	196/64	244/64	273/64	869
Average _____	24/64	30/64	34/64	108.6

*Died during the summer.

TABLE 9.—COMPARISON OF TWO-YEAR-OLD APPLE TREES TRANSPLANTED IN AUTUMN WITH TWO-YEAR-OLD TREES TRANSPLANTED IN SPRING

Autumn-planted, 1913				Spring-planted, 1914		
Variety	Avg. Diam. growth prior to Aug. 14, '14, inches	Avg. for entire season, inches	Avg. length growth, inches	Avg. Diam. growth prior to Aug. 14, '14, inches	Avg. for entire season, inches	Avg. length growth, inches
Transparent	12/64	22/64	207.8	3/64	10/64	104.3
Grimes _____	9/64	15/64	145.7	6/64	10/64	108.6
Total _____	21/64	37/64	353.5	9/64	20/64	212.8
Average _____	10/64	18/64	176.7	4/64	10/64	106.4

TABLE 10.—GROWTH DURING SUMMER OF 1914 OF EARLY AUTUMN PLANTED ONE-YEAR-OLD JONATHAN, WINESAP AND EARLY HARVEST APPLE TREES
Fifteen trees planted in autumn, November 8, '13

No. of tree	Diameter when set, inches	Diameter, Aug. 14, 1914, inches	Diameter, Nov. 20, 1914, inches	Amount of twig growth, inches
1°	8/64	27/64	35/64	171
2°	12/64	16/64	44/64	258
3°	8/64	28/64	36/64	339.5
4	16/64	36/64	45/64	255
Average	11/64	27/64	40/64	255.9
Winesap—				
5°	8/64	29/64	41/64	184
6°	16/64	32/64	36/64	292
7°	8/64	20/64	22/64	78
8	16/64	28/64	36/64	130.5
9°	8/64	25/64	36/64	181
10	12/64	29/64	40/64	181
11°	12/64	29/64	38/64	156.5
Average	11/64	27/64	36/64	171.9
Early Harvest—				
12	12/64	30/64	39/64	173
13°	8/64	20/64	34/64	117
14	20/64	33/64	44/64	162
15°	12/64	26/64	30/64	55
Average	13/64	27/64	37/64	126.7
Total	176/64	414/64	556/64	2733.5
Average	12/64	27/64	37/64	182.2

*Mulched at time of planting.

TABLE 11.—GROWTH DURING SUMMER OF 1914 OF LATE AUTUMN PLANTED ONE-YEAR-OLD JONATHAN, WINESAP AND EARLY HARVEST APPLE TREES
15 trees planted in autumn, December 6, 1913

No. of trees	Diameter when set, inches	Diameter Aug. 14, 1914, inches	Diameter, Nov. 20, 1914, inches	Amount of twig growth, inches
Jonathan—				
1	8/64	26/64	34/64	135
2	12/64	33/64	43/64	277
3 M	8/64	27/64	34/64	183
4 M	12/64	33/64	44/64	262
Average	10/64	30/64	39/64	214
Winesap—				
5 M	12/64	35/64	39/64	251
6	12/64	34/64	44/64	352
7 M	8/64	31/64	46/64	287
8	12/64	31/64	45/64	218
9 M	8/64	29/64	41/64	264
10	12/64	34/64	43/64	340
11 M	12/64	30/64	40/64	131
Average	11/64	32/64	44/64	265.7
Early Harvest—				
12	12/64	30/64	42/64	92
13 M	8/64	30/64	29/64	132
14	20/64	36/64	43/64	193
15 M	12/64	34/64	40/64	163
Average	13/64	32/64	33/64	137.5
Total	160/64	473/64	567/64	3280
Average	11/64	31/64	42/64	218.6

M—mulched at time of planting.

TABLE 12.—GROWTH DURING SUMMER OF 1914 OF SPRING PLANTED ONE-YEAR-OLD JONATHAN, WINESAP, AND EARLY HARVEST TREES
Fifteen trees planted April 18, 1914

No. of tree	Diameter when set, inches	Diameter, Aug. 14, 1914, inches	Diameter, Nov. 20, 1914, inches	Amount of twig growth, inches
Jonathan—				
1	12/64	21/64	27/64	110
2	12/64	21/64	30/64	185
3	16/64	21/64	28/64	135
4	16/64	27/64	27/64	272
Average	14/64	23/64	24/64	175.5
Winesap—				
5	12/64	25/64	30/64	102
6	12/64	23/64	26/64	62.5
7	12/64	15/64	24/64	14
8	12/64	25/64	31/64	128
9	12/64	22/64	28/64	100
10	12/64	21/64	26/64	75
11	16/64	20/64	24/64	51
Average	13/64	22/64	27/64	75.5
Early Harvest—				
12	16/64	22/64	23/64	44
13	12/64	23/64	28/64	88.5
14	20/64	24/64	27/64	47
15	16/64	21/64	24/64	97.5
Average	16/64	23/64	26/64	68.7
Total	204/64	331/64	403/64	1511.5
Average	14/64	22/64	27/64	100.7

TABLE 13.—COMPARATIVE GROWTH DURING THE SUMMER OF 1914. ALL AUTUMN AND SPRING PLANTED JONATHAN, WINESAP AND EARLY HARVEST APPLE TREES

Time of planting	Avg. Diam. when set, inches	Avg. Diam. Aug. 14, 1914, inches	Avg. Diam. Nov. 20, '14, inches	Avg. Length growth, inches
Nov. 8, '13	12/64	27/64	37/64	182.2
Dec. 6, '13	11/64	31/64	42/64	219.3
Average	11/64	29/64	39/64	200.7
Apr. 18, '14	14/64	22/64	28/64	100.7

TABLE 14.—COMPARATIVE AVERAGE GROWTH DURING THE SUMMER OF 1914, OF ALL AUTUMN- AND SPRING-PLANTED TRANSPARENT, GRIMES, JONATHAN, WINESAP AND EARLY HARVEST APPLE TREES

Time of planting	Diameter when set, inches	Diameter, Aug. 14, 1914, inches	Diameter, Nov. 20, 1914, inches	Amount of length growth, inches
Fall	16/64	33/64	41/64	188.7
Spring	23/64	28/64	34/64	106.2

Tables 7 and 8 show that fall-set Grimes trees made better growth than Grimes set in spring but that these differences were less marked than in the case of the Jonathan and Transparent trees heretofore discussed. In diameter growth, previous to August 14, the fall-planted trees made about two-thirds of their total annual increment while the spring-set trees made more than one-half their annual increase. At the close of the growing season the increase in diameter of the fall-set trees exceeded that of the spring-set trees by 14 per cent. In total annual twig growth, the fall-set trees exceeded that of the spring-planted trees in the relation of 145.7 inches, for the former, to 108.6 inches for the latter. These data, taken in connection with general observations that have been made upon numerous other fall and spring plantings of Grimes, indicate that this variety profits less by fall planting than do some of the other varieties.

The Grimes has a weak trunk, however, and suffers larger mortality due to transplanting than do most varieties of apples grown in this region. It will be observed that three of the Grimes trees planted in spring died in early summer. Perhaps fall planting may be of sufficient importance in lessening mortality in this variety to be reckoned as an important factor.

Comparing Tables 10 and 11 it will be seen that the average diameter growth and twig growth of trees planted December 6, exceeded the growth made by trees planted November 8. This difference was most marked in the case of the Winesap. The Jonathan trees seem to be an exception. It should be borne in mind, however, that this variation is due to tree No. 3, Table 10, which made very exceptional growth, no doubt due to individual variation.

In addition to the trees recorded in the foregoing tables, repeated early and late fall-plantings have been made and observed on the Experiment Station grounds as well as in commercial orchards. These observations indicate uniformly that late fall planting is preferable to early fall planting for this region.

Comparing Tables 10 and 11 with Table 12, it is shown that either early or late fall-planting gave better results than spring planting; thus confirming the results shown in previous tables.

A comparison of the growth of early spring- and late spring-planted apple trees is made in Table 22. It will be seen that the trees planted on March 29 made far better growth than those planted April 28. In the same table it will also be seen that the early spring-planted trees outgrew those planted in the fall, while the lat-

ter made far better growth than those planted in late spring. This is the only instance, at the Missouri Experiment Station, in a series of years, in which apple trees planted at any time in spring have outgrown similar trees planted in the fall. The exceptional results recorded in this table are probably due to unusual conditions. The fall of 1916 was exceptionally dry. There was very little winter precipitation. The soil was very dry during the autumn and winter. Unfavorable conditions for fall-planted trees are further emphasized by the fact that winter wheat suffered to an unusual degree, large areas being so badly winter killed that they were plowed up and planted to other crops in the spring of 1917. Fall-planted trees dried out far worse than usual during the winter. By the last of March the soil was just moist enough for ideal planting conditions. These conditions prevailed for a month after the trees were set on March 29. The soil was not too wet and cold, as is often the case in early spring, but was sufficiently moist for the early spring-planted trees to make a most favorable start. Since these trees had stood with their roots undisturbed in the nursery during the winter, they had not dried out as did the fall-planted trees.

Conditions were far less favorable than usual for the late spring-planted trees. The weather was warm and dry at the time they were set. Their leaves appeared before their roots became established in the soil. The summer was dry, affecting them more unfavorably than it did the trees which were planted under the more favorable conditions of the previous month.

Additional early and late spring plantings have been made, altho not located where they could be given frequent observation or where detailed records could be made. The results have been observed, however, in numerous seasons.

TABLE 15.—COMPARATIVE GROWTH DURING THEIR SECOND SUMMER (1915) OF AUTUMN- AND SPRING-PLANTED TRANSPARENT APPLE TREES

Nineteen trees set November 8, 1913				Fifteen trees set April 27, 1914			
Tree No.	Diam. Nov. 30, 1915, inches	Branches	Length growth, inches	Tree No.	Diam. Nov. 30, 1915, inches	Branches	Length growth, inches
1	1 23/64	44	1081	1	46/64	—	25
2	1 6/64	17	660	2	66/64	22	536
3	1 10/64	16	343	3	56/64	14	168
4	—	—	—	4	1 16/64	37	808
5	1	10	198	5	1 12/64	26	628
6	1 10/64	24	369	6	49/64	—	60
7	1 14/64	36	830	7	52/64	6	84
8	1 34/64	55	863	8	62/64	23	606
9	1 11/64	27	589	9	1 3/64	33	656
10*	—	—	—	10	1 22/64	33	795
11	1 1/64	19	485	11*	—	—	—
12	1 12/64	27	689	12*	—	—	—
13	1 12/64	36	774	13†	—	—	—
14	59/64	32	532	14†	—	—	—
15	1	40	542	15	1 18/64	42	940
16	51/64	18	294	16	—	—	—
17	61/64	28	529	—	—	—	—
18	78/64	13	198	—	—	—	—
19	56/64	27	425	—	—	—	—
Total	18 16/64	469	9401	Total	11	236	5306
Average	1 4/64	27.5	553	Average	1.1	26.2	482.4

*Blight and canker.

†Died during summer 1914.

TABLE 16.—COMPARATIVE GROWTH DURING THEIR SECOND SUMMER (1915) OF AUTUMN AND SPRING-PLANTED GRIMES APPLE TREES

Twelve trees set December 6, 1913				Eleven trees set April 18, 1914			
Tree No.	Diam. Nov. 30, 1915, inches	Branches	Length growth, inches	Tree No.	Diam. Nov. 30, 1915, inches	Branches	Length growth, inches
1	—	16	242	1*	—	—	—
2	—	16	288	2*	—	—	—
3	1 19/64	29	649	3*	—	—	—
4	1 17/64	28	686	4†	—	—	—
5	1 44/64	59	1311	5	56/64	23	370
6	1 12/64	27	460	6	1 7/64	27	533
7	—	38	748	7	48/64	22	193
8	1 14/64	25	345	8	53/64	22	213
9	1 19/64	23	526	9†	—	—	—
10	1 7/64	31	505	10	1 12/64	38	590
11	1 14/64	26	468	11†	—	—	—
12	1 7/64	23	404	—	—	—	—
Total	11 25/64	341	6682	Total	4 50/64	132	1899
Average	1 17/64	28.4	556.8	Average	61/64	26.4	375.8

*Trees died during the summer of 1914.

†Killed by blight and canker infection.

TABLE 17.—SHOWING GROWTH DURING THEIR SECOND SUMMER (1915) OF EARLY AND LATE AUTUMN-PLANTED JONATHAN, WINESAP AND EARLY HARVEST APPLE TREES

Fifteen trees planted Nov. 8, 1913				Fifteen trees planted Dec. 6, 1913			
Tree No.	Diam. Nov. 30, 1915, inches	Branches	Length growth, inches	Tree No.	Diam. Nov. 30, 1915, inches	Branches	Length growth, inches
Jonathan—				Jonathan—			
1* .....	.....	.....	.....	1* .....	.....	.....	.....
2* .....	.....	.....	.....	2* .....	.....	.....	.....
3* .....	.....	.....	.....	3* .....	.....	.....	.....
4* .....	.....	.....	.....	4* .....	.....	.....	.....
Winesap—				Winesap—			
5	15/64	33	785	5	1 18/64	43	790
6	48/64	.....	.....	6	60/64	24	407
7	48/64	15	285	7	1 24/64	56	1374
8	1 1/64	25	573	8	1 22/64	45	1026
9	58/64	20	422	9 .....	.....	.....	.....
10	60/64	15	374	10 .....	.....	.....	.....
11	62/64	14	391	11	59/64	18	293
Average....	.....	20	471.6	Average	.....	37	778
Early Harvest—				12	55/64	17	342
12	54/64	17	374	13	56/64	18	442
13	44/64	7	161	14	60/64	10	201
14	1 1/64	21	467	15	57/64	13	280
15	52/64	15	225	Average	.....	15	316.2
Average....	.....	15	307				
Total	9 59/64	182	4051	Total	9 27/64	243	5155
Average....	57/64	18.2	405.7	Average	1 3/64	27	572.7

*Trees cut back severely because of blight and canker infection.

TABLE 18.—GROWTH DURING THE SUMMER OF 1915 OF SPRING-PLANTED JONATHAN, WINESAP AND EARLY HARVEST APPLE TREES

Tree No.	Diameter, Nov. 30, 1915, inches	Branches	Length growth, inches
1* .....	.....	.....	.....
2* .....	.....	.....	.....
4* .....	.....	.....	.....
4* .....	.....	.....	.....
Winesap—			
5	55/64	15	246
6	50/64	14	341
7	45/64	17	267
8*	55/64	.....	.....
9	52/64	14	409
10	45/64	20	711
11	33/64	7	163
Average .....	.....	15	356
Early Harvest—			
12	34/64	13	126
13 .....	.....	8	199
14	44/64	13	173
15* .....	.....	.....	.....
Average .....	.....	.....	166
Total	6 34/64	121	2635
Average	46/64	13.4	292.7

*Trees cut back severely on account of blight and canker infection.

TABLE 19.—COMPARISON OF THE AVERAGE GROWTH DURING THE SUMMER OF 1915 OF ALL AUTUMN AND SPRING-PLANTED JONATHAN, WINESAP AND EARLY HARVEST APPLE TREES

Time of Planting	Avg. Diam. Nov. 30, 1915, inches	No. of Branches	Avg. Length growth, inches
Nov. 8, 1913	57/64	18.2	405.7
Dec. 6, 1913	1 3/64	27	572.7
Average	62/64	22.6	489.2
April 18, 1914	46/64	13.4	292.7

TABLE 20.—COMPARATIVE INCREASE IN GROWTH DURING THE SEASONS OF 1914 AND 1915 OF APPLE TREES SET NOVEMBER 8, 1913, AND SET DECEMBER 6, 1913

Trees set November 8, 1913			Trees set December 6, 1913		
Year	Average increase in growth in inches		Year	Average increase in growth in inches	
	Diameter	Length		Diameter	Length
1914	25/64	207.8	1914.....	31/64	219.3
1915	20/64	405.7	1915.....	25/64	572.7

TABLE 21.—COMPARISON OF THE AVERAGE GROWTH DURING THE SUMMER OF 1915 OF ALL AUTUMN AND SPRING-PLANTED TRANSPARENT, GRIMES, JONATHAN, WINESAP AND EARLY HARVEST TREES

Time of Planting	Avg. Diam. Nov. 30, 1915, inches	No. of Branches	Avg. length growth, inches
Fall	1 21/64	25.2	507.3
Spring	1 16/64	22.0	382.1

TABLE 22.—GROWTH DURING SUMMER OF 1917 OF LATE AUTUMN, EARLY SPRING
AND LATE SPRING-PLANTED APPLE TREES

Fall-planted Dec. 2, '16				Spring-planted March 29, '17				Spring-planted April 28, '17			
Tree No.	No. of twigs	Length inches	Wt. of Prunings, grams	Tree No.	No. of twigs	Length inches	Wt. of Prunings, grams	Tree No.	No. of twigs	Length inches	Wt. of Prunings, grams
Wincsap—											
1341.....	7	132	20	1381.....	12	168	35	1421.....	8	96	22
1342.....	10	139	22	1382.....	8	112	25	1422.....	11	86	14
1343.....	11	125	22	1383.....	11	151	27	1423.....	4	6	0
1344.....	8	68	9	1384.....	10	156	29	1424.....	8	86	10
1345.....	9	139	23	1385.....	6	84	13	1425.....	11	46	8
Average.....	9.0	120.6	19.4	Average.....	9.0	134.2	23.8	Average.....	6.4	64	10.8
Gano—											
1346.....	12	80	10	1386.....	12	66	8	1426.....	6	65	20
1347.....	11	84	15	1387.....	10	74	10	1427.....	4	54	9
1348.....	10	72	15	1388.....	10	129	18	1428.....	8	6	0
1349.....	14	139	27	1389.....	8	42	6	1429.....	6	78	9
1350.....	7	60	10	1390.....	6	102	16	1430.....	10	111	10
Average.....	10.8	87.0	15.4	Average.....	9.2	84.6	11.6	Average.....	6.8	60.8	9.6
Jonathan—											
1351.....	8	139	18	1391.....	7	80	11	1431.....	7	60	5
1352.....	7	146	19	1392.....	11	154	30	1432.....	7	98	13
1353.....	6	98	20	1393.....	5	64	9	1433.....	6	76	13
1354.....	8	110	15	1394.....	7	56	7	1434.....	4	9	0
1355.....	8	173	32	1395.....	4	96	12	1435.....	2	12	5
Average.....	7.4	133.2	20.8	Average.....	6.8	90.0	13.8	Average.....	5.1	51.0	7.2

Early spring planting is probably to be preferred to late spring planting if the soil is dry enough to be worked nicely in March, and especially if the trees to be transplanted are standing in the nursery where their buds are likely to start early. Early spring planting usually proves better than later planting if the following summer proves to be dry and hot.

There is perhaps no advantage in early spring planting if the soil is wet and cold and especially if the trees are stored where they can be kept dormant. Most Missouri soils are fine, clay loams rather than sandy and well drained. Frequently these soils are too wet to work to the best advantage in very early spring.

FALL AND SPRING PLANTING OF SOUR CHERRIES

In Missouri it has been customary to plant sour cherries (sweet cherries are not generally grown in the state) and other stone fruits, in the spring. They are regarded as being the most difficult of our orchard fruits to transplant successfully. Planted in the spring, often from one-third to two-thirds of the trees die. This large mortality of cherry trees necessitates repeated replanting before a full stand of trees is secured in the orchard.

Repeated spring plantings of sour cherries at the Experiment Station have usually resulted in similar mortality of the trees. Only in occasional seasons, when soil and weather conditions were favorable at the time of planting, and when well-distributed rainfall kept the soil neither too wet nor too dry thruout the summer, has spring planting resulted in a good stand of trees. If the summer is too wet, the trees seem to thrive no more successfully than during summer drouth. The roots of sour cherries apparently require a moderate but constant supply of moisture in a well-aired soil but suffer when the soil is saturated with water, which shuts out air for any great length of time. This is especially true of young cherry trees recently transplanted.

TABLE 23.—GROWTH IN 1914 OF AUTUMN-PLANTED MONTMORENCY CHERRY TREES

Six trees set in autumn, Nov. 20, 1913

No. of Trees	Diameter when set, inches	Diameter, Aug. 14, 1914, inches	Diameter, Nov. 20, 1914, inches	Amount of twig growth, inches
1	32/64	33/64	33/64	50.75
2	32/64	33/64	35/64	89.0
3	28/64	33/64	37/64	97.0
4	36/64	36/64	40/64	31.5
5	28/64	37/64	39/64	101.5
6	32/64	36/64	37/64	80.0
Total	188/64	207/64	227/64	449.75
Average	31/64	35/64	38/64	74.8

TABLE 24.—GROWTH IN 1914 OF SPRING-PLANTED MONTMORENCY CHERRY TREES

Six trees set in spring April 14, 1914

No. of Trees	Diameter when set, inches	Diameter, Aug. 14, 1914, inches	Diameter, Nov. 20, 1914, inches	Amount of twig growth, inches
1*	32/64	.....	.....	.....
2*	32/64	.....	.....	.....
3	28/64	32/64	33/64	33.5
4*	32/64	.....	.....	.....
5*	24/64	.....	.....	.....
6	32/64	35/64	36/64	32
Total	180/64	67/64	69/64	65.5
Average	30/64	33/64	34/64	32.7

*Trees died during summer of 1914.

TABLE 25.—COMPARATIVE GROWTH DURING THE SUMMER OF 1915 OF AUTUMN AND SPRING-PLANTED MONTMORENCY CHERRY TREES

Six trees set in autumn, Nov. 20, 1913				Six trees set in spring, April 14, 1914			
Tree No.	Diam. Nov. 30, 1915, inches	Branches	Length growth, inches	Tree No.	Diam. Nov. 30, 1915, inches	Branches	Length growth, inches
1	1 4/64	36	401.5	1* .....	.....	.....	.....
2	1 16/64	47	656.5	2* .....	.....	.....	.....
3	1 11/64	48	576	3	1	42	434
4	62/64	31	280	4* .....	.....	.....	.....
5	1 6/64	90	585	5* .....	.....	.....	.....
6	62/64	24	190	6	1 6/64	39	418
Total	6 33/64	276	2689	Total	2 6/64	81	852
Average	1 5/64	46	248.1	Average	1 3/64	40.5	426

*Died during summer of 1914.

The occasional fall plantings of sour cherry trees, made at the Experiment Station, have uniformly resulted in a good stand of trees. Sour cherries set in the fall have uniformly transplanted as successfully as apples or other fruits.

Tables 23, 24, and 25 show results which are quite typical as a comparison of spring and fall planting of sour cherries. The trees set in the fall of 1913, transplanted successfully, all of them made fine growth the following summer and, at this writing, July, 1918, all of them are in vigorous and healthy condition. They produced a good crop of fruit this year. Two-thirds of the trees set in the spring of 1914, started growth but died before midsummer. The trees which lived thru the first summer are now doing well but have not quite caught up with the fall-planted trees.

The average annual twig growth of the fall-set trees exceeded that of the spring-set trees which lived, in the proportion of 74.8 inches to 32.7 inches. Since two-thirds of the spring-set trees died before they made appreciable growth it is evident that the one-third which lived were the strongest growing specimens of the spring-set lot. If these are compared with the one-third of the fall-set trees which made the strongest growth the relation is 99 inches average length of twig growth, and 10/64 inches average diameter increase, for fall-set trees, and 32.7 inches length growth and 4/64 diameter increase, for spring-set trees.

A detailed record of the growth of these cherry trees is shown in Table 25. If the spring-set trees which died are disregarded, it is apparent that those which lived partly overtook the average of the entire number planted in the fall. If the living spring-set trees are compared with the strongest of the fall-set trees a marked advantage is shown in the latter.

FALL AND SPRING PLANTING OF VARIOUS SPECIES OF TREES

Peach trees prove to be planted more safely in spring than in the fall, in central Missouri. If a severe winter follows autumn planting of the peach, often the trees are killed. Even in milder winters the wood is usually injured sufficiently to turn brown within. With such injury the trees frequently die and at best make poor growth.

Peach trees which have a well-established root system usually recover from such winter injury if their roots remain undisturbed

and if they are properly cut back. The root system of young peach trees, even in the nursery, is rarely injured by the coldest winters in central Missouri, providing it is allowed to remain undisturbed. Fall-transplanted peach trees do not establish sufficient root system to winter safely. Even their root system is usually injured and if the winter is severe both tops and roots are usually injured beyond recovery. In the southern counties of the state, however, peach trees are frequently transplanted in the fall with good results.

Japanese plums and other slightly tender species subject to winter injury in this section are more safely planted in the spring.

Pears and hardy plums apparently profit by fall planting to about the same degree as do apples.

Persimmons, native walnuts, chestnuts, hickories, and pecans have been transplanted at various seasons of the year. The best results have been secured by planting these species just as their new leaves are pushing out in spring. They do not transplant successfully when fully dormant, either in fall or early spring.

In the development of the grounds, during the last twenty years, large numbers of ornamental trees and shrubs—both deciduous and evergreen—have been set at various seasons of the year. They have been set when and where they were needed for ornamental purposes rather than to determine the most favorable season for transplanting. The results of this general experience, however, may have some value, especially to those who have not had opportunity for extensive observation of the results of planting at different seasons.

Thoroly hardy deciduous trees and shrubs (with the exception of persimmons and nut trees previously discussed) have usually made better growth when transplanted in late autumn. If the soil is very dry in autumn, as occasionally happens in this section, transplanting may be more safely postponed until early spring.

Slightly tender deciduous species including magnolia, tulip (or yellow poplar), Vitex, sweet gum, and some of the soft wood species whose twigs tend to shrivel and dry out in severe winters, are safer planted in the spring. The best time in spring is not yet fully determined. It may vary with the individual species. Magnolias have done best if transplanted during their early blossoming period; the tulip trees and sweet gum just as their buds were bursting; and most other species before their buds start growth.

The best season for transplanting coniferous evergreens is a vexed question, especially in the central west where fluctuations in

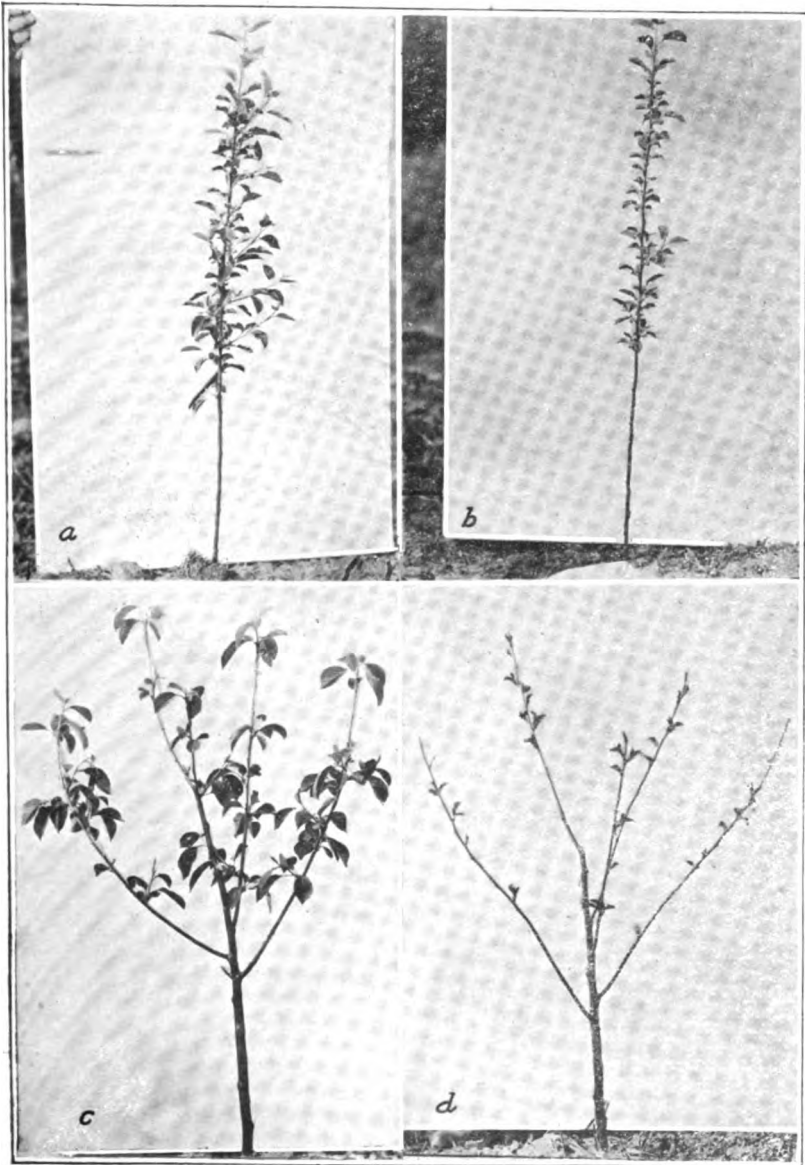


PLATE 1.—Showing the greater average growth on May 11, 1914, on Jonathan apple trees planted December 8, 1913, (*a*), and planted April 18, 1914 (*b*). Also showing the average difference in growth on May 11, 1914, of Montmorency cherry trees transplanted November 20, 1913 (*c*), and transplanted April 14, 1914 (*d*).

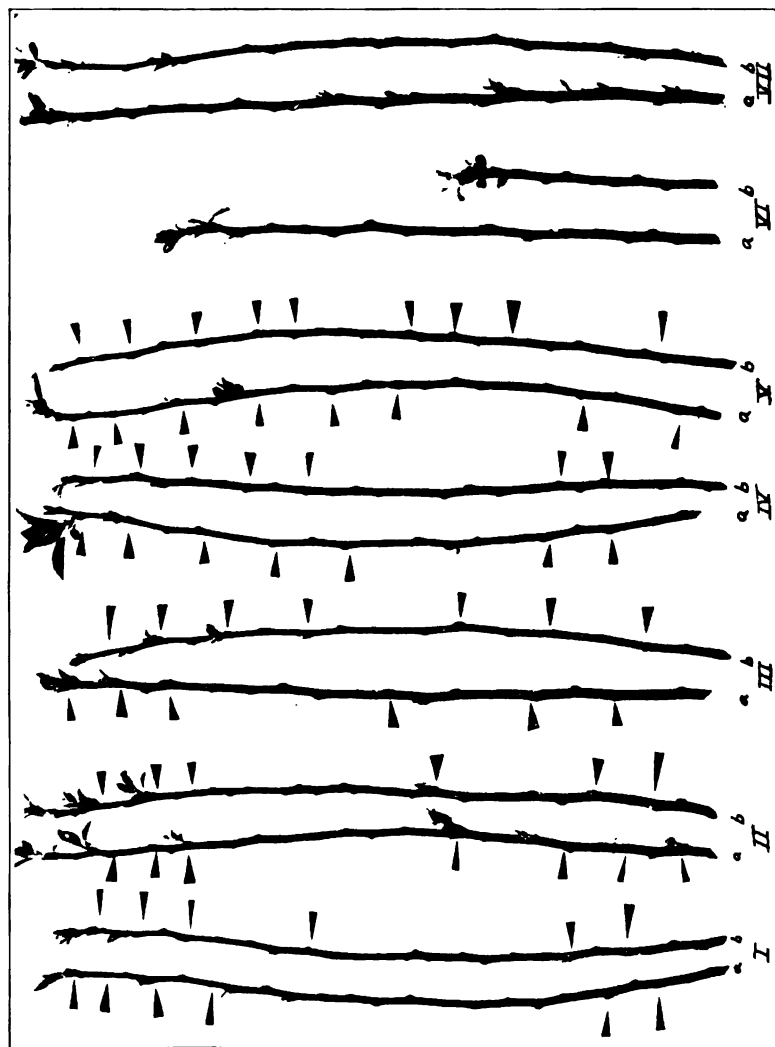


PLATE II.—The effect of wounding upon the activity of dormant buds. Twigs from Delicious apple treated February 22, 1916, in the following manner: Group I, wounded below the alternate buds; Group II, wounded above alternate buds; Group III, wounded above and below alternate buds; Group IV, wounded on one side of alternate buds; Group V, wounded on both sides of alternate buds; Group VI, pruned to different lengths; Group VII, checks. Arrows indicate some of the wounded buds. "a" indicates wounding by incision thru the cortex; "b" indicates wounding by notching, a small portion of the cortex being removed.

weather conditions are often extreme. The evergreens are difficult to transplant. This is no doubt due to the fact that they carry their leaves thruout the year and consequently evaporate water thru these leaves, as opposed to deciduous trees in which evaporation is greatly reduced during the dormant period. The roots of evergreens cannot endure even brief exposure to the air without severe injury. For that reason their roots should be protected with moist soil, wet burlap, or other moist packing, at all times while being handled.

There is perhaps not a month in the year that has not been recommended as the best time to transplant evergreens for certain localities. At the Missouri Experiment Station a larger or smaller number of evergreens have been transplanted at various seasons every year for a quarter of a century. In nearly every season the best results have been secured with trees transplanted in late spring, just as new growth was beginning. The next most favorable time has proved to be in early fall, after growth has ceased, but before the trees have matured their growth for winter.

The resin in the ducts of evergreens appears to be very thick during the winter. If the trees are handled in very late fall, during the winter, or in late spring, this resin hardens quickly, the cut ends of the roots become covered with a hard resinous coat which does not emit new roots, and even the twigs, leaves and main roots appear to be so hardened with resin as to obstruct the passage of water. There are two periods, one just after growth ceases in the fall, and the other just after growth begins in spring when sap movement appears not to be obstructed by hardening of the resin.

If the soil is moist and the atmosphere is humid, early autumn planting gives good results under Missouri conditions. If the soil and air are dry in early autumn, as is often the case, planting should be delayed until growth starts in spring.

ROOT FORMATION OF EARLY AND LATE FALL-PLANTED APPLE TREES

The chief advantages ascribed to fall transplanting of deciduous trees are that the soil becomes thoroly settled about their roots, that the wounds at the ends of the cut-back roots become calloused over, and that the new roots may be formed before the trees leaf out in spring. Practically all of those who favor fall transplanting have advised that the work be done as early in autumn as the trees are in condition to move from the nursery, in order that their roots

may become reestablished before the ground freezes. It seems to have remained an unsettled question, however, as to what extent the success of fall planting may depend upon callousing of the wounds or the formation of new roots before winter sets in. To just what extent the new root system does become "newly established" in the fall has been a matter of doubt. In view of the fact that late fall planting has given better results than early fall planting at the Missouri Experiment Station it is of interest to compare the root development of early and late fall-set trees.

Referring to the available literature on the root growth of trees, this statement by Jost³¹ is of interest, "Owing to the obvious difficulties of research, the problems with root growth have been as yet little elucidated." Sorauer⁴⁷ states that "the shedding of the leaves ushers in a period of rest. As this partly depends upon the gradual decrease of temperature, the upper portions of the stem, which are exposed to the atmosphere, may have completely entered the period of rest, while the roots which lie in the warmer layers of the soil, are still continuing their growth in thickness. This activity may sometimes last until January, and then only can we say that the plant is entirely at rest."

With respect to callousing of the wounds on the roots in autumn after trees are transplanted, Lindley³⁶ states, "If at that time [after shedding of the leaves] a root is wounded, a process of granulation or cicatrication will commence, just as it does in cuttings; and from that granulation, which is a mere development of the horizontal cellular system, roots will eventually proceed—the sooner the wound is made the better, because it has the longer time to heal; and therefore the earlier in autumn transplanting is effected, the less injury will be sustained." Koopman³³ also evidently regards the callousing of the roots of early fall-planted trees as being an important factor when he warns against their exposure in this statement, "Once dried out, the cut surfaces do not heal themselves again." Others believe, however, that new root growth does not start from the callous but that new rootlets push out from the sides of the essential roots. Bedford and Pickering¹ (1908, pp. 3-4) make the following statement, "The whole subject to be sought in planting a tree is to secure the formation of fresh rootlets from the main roots, and not to preserve the fibrous roots, which, having lost their root tips are little better than dead encumbrance to the tree." They also further state that if the tree is lifted a few weeks after transplanting, it will be seen "that, in the case of a main root which has been trimmed back

rather short, there will be considerable development of new rootlets close to the cut end, tho not actually from the cut end itself."

Card¹⁰ (1898) found that apple trees planted at the Nebraska experiment station October 22, 1897, formed a few short root tips before November 16 of the same fall. Peach trees planted at the same time showed no root growth on the latter date, altho root growth was still active on peach trees which had not been transplanted. An examination of the fall-transplanted apple and peach trees April, 1898, showed that root growth was progressing from the sides of the main roots and that "the cut surfaces were beginning to callous, none having apparently taken place during the fall and winter." He found that at the Missouri Botanical Garden apple trees which were transplanted November 3, had formed roots one to two inches long by December 14, but that no calluses had formed. Peach trees transplanted on the former date had formed no roots but the callusing of the wounds had begun.

At the Missouri Experiment Station observations on the root development of fall-planted apple trees were made in 1895. During the last week in October, two-year-old trees of several representative varieties were transplanted from the Experiment Station nursery. Specimen trees were taken up from time to time and their roots examined. During the first part of December there were no evidences of the starting of new roots on any of the trees examined up to that time. During the last part of December a few new roots were observed on a part of the trees. When the ground thawed in early spring a liberal number of new roots were observed on all the trees examined. Those transplanted in spring put out their leaves before their new root growth started. It was observed that once the spring-planted trees started new leaf growth they then made no more progress for a time, leaf growth apparently being at a standstill until new roots became established. The fall-planted trees had numerous new roots before they came into leaf, and made steady growth after their first spring start.

Similar observations have been repeated, from time to time, in subsequent years. The first new root growth, on fall-transplanted apple trees, was observed from late December to early January in different years. In each case the new growth has occurred on the roots below the frost line, after the surface soil was frozen to a depth of a few inches. Spring-transplanted apple trees have repeatedly been observed to put out leaves ahead of new root formation. Once this new leaf growth was formed, further progress was

usually observed to be delayed until new root growth became established later in the spring. Mortality of spring-planted trees has apparently been due to loss of water thru their leaves which started ahead of their roots.

Perhaps the most thoro study of this matter at the Missouri Experiment Station was made during 1915-16 by Mr. L. E. Jesseman, graduate scholar in the department of horticulture. His work was done under the writer's direction, as part of a problem for his Master's thesis. Mr. Jesseman's statement follows:

On October 30, 1915, or as soon as ninety per cent of the leaves were shed, the writer transplanted several one-year-old trees representing the varieties, Jonathan, Winesap, and Gano. On December 2, more than a month later, when it was apparent that the ground would soon be frozen, an additional planting was made, comprising five Jonathans, five Ganos and five Winesaps. These trees were one-year cut-backs; that is, one-year-old tops on three-year-old roots. The trees in each set were lifted from the nursery and replanted immediately without undue exposure of the roots. The roots were pruned where necessary.

The first examination of the root systems of these trees was made December 1. Tree No. 3 of each variety planted October 30, was carefully lifted and the soil washed from the roots with a gentle stream of water. It was found that no new roots had formed, neither had any callusing of the cut surfaces taken place. The numerous root hairs and many of the finer rootlets, which were observed when the trees were planted, had died or become brown and shriveled in appearance. These trees were replanted for further observation. Examination of a tree in the nursery which had not been disturbed showed the root growth was still active.

The time of the next observation was January 22, following a warm period of several days duration. The ground was free from frost for approximately five inches below the surface, the frost extending to a depth of nine inches. This time trees No. 2 and 3 of each variety of the early planting were lifted, and their roots examined. It was found that there were thirteen new root tips on the Gano, six on the Jonathan and five on the Winesap. The roots varied in length from $1/16$ to $1/2$ inch. It was noted at the time of planting that on the No. 2 Jonathan there were large, fleshy root tips growing from the stem. When examined in January, one of these roots was missing, and three had lengthened considerably, one of them being $1 1/8$ inches long. Trees No. 3 of each variety, which were lifted and replanted December 1, still showed no evidence of new root growth.

A specimen tree from the late fall planting, December 2, was taken up January 29. It was seen that there were two large root tips, $1/4$ to $1/2$ inch long, about two inches from the end of one of the main roots. There was a very vigorous growth of root hairs taking place on all of the fibrous roots. Root growth seemed to be more active than in the case of trees transplanted October 30. No calluses were observed on either the early- or the late-planted trees.

Upon examining the tree which had remained undisturbed in the nursery, it was found that root growth was still active below the frost line.

It was determined, therefore, from the above observations that no new growth of roots or callusing of wounds occurred before December 1 on trees transplanted October 30. It was evident, however, that formation of new roots had been going on for a sufficient length of time previous to January 22 to form roots $1/2$ inch in length. It appeared that trees transplanted in late autumn, December 2, began new root growth at approximately the same time as those set 33 days earlier. It was also clearly shown that root formation is not necessarily preceded by callusing of the cut surfaces of the roots.

ROOT FORMATION OF SPRING-TRANSPLANTED APPLE TREES

A study of the resumption of root growth of spring-transplanted trees should be associated with what is known of the normal root growth of established trees whose roots have not been disturbed by transplanting. With reference to the resumption of root growth in spring, Engler²⁰ states, "It is found that various species begin root activity before bud development; namely, Zurich in March and April, a few days to four weeks before buds open. In high altitudes the time difference becomes smaller and in some cases vanished entirely." Goff²⁶ in Wisconsin observed root growth of the apple and other trees starting about March 31, before the buds had preceptibly swollen. He also found the root growth in early spring is most active near the surface of the soil and that it starts where it left off in autumn, at the tips of the finer roots. Card¹⁰ has made similar observations upon the root growth of established trees in Nebraska.

Observations at the Missouri Experiment Station indicate that the root systems of established fruit trees have no such definite rest period as do their tops. Repeated observations of fruit trees taken up at intervals from the time they shed their leaves in the fall until they leaf out in spring indicate that root growth continues after the trees shed their leaves; that it may progress slowly, below the frost line, at any time during the winter and that rapid root growth begins in spring, especially on roots near the surface, before the buds begin growth. On undisturbed trees this growth progresses mainly from the tips of the finer roots.

Observation of transplanted trees shows that the operation of transplanting is followed by a cessation of root growth which lasts over a considerable period, no matter how carefully the work is

done. On fall-planted trees root growth is resumed before mid-winter, below the frost line, from the deeper main roots, and may continue all winter below the frost line. On spring-planted trees root growth is delayed until after the buds start and is resumed mainly from the larger roots which first receive warmth, nearest the surface of the soil. Regardless of the season of transplanting, the small fibrous roots rarely resume growth but for the most part wither away and, as Bedford and Pickering³ have said, they are an incumbrance to the transplanted tree.

It is an interesting fact that trees which have been dug in the fall and "heeled in" over winter, or trees which have been received from distant nurseries, usually have started leaf growth and root growth at about the same time when spring-planted. Trees that are handled enough to lose some of the water content, between the time of lifting from the nursery and setting in the orchard, are usually delayed somewhat in putting out their leaves. In some cases leaf growth has not begun until new root growth is underway.

In the spring of 1916 this proved true of trees transplanted from the Station nursery in which they were handled with the least possible exposure. These trees were set and observed by Mr. Jesseman as a part of his work, referred to previously. It is of interest to quote his record of these trees:

On March 25, 1916, five trees each of the Jonathan, Winesap and Gano varieties were transplanted. (These trees had been selected in the fall to duplicate the fall-set trees and were allowed to remain in the nursery during the winter.) Four days later, an equal number of trees of the same varieties were transplanted. (These were the trees selected for comparison with those planted December 2, 1915. Root growth was progressing rapidly upon these trees when lifted from the nursery.)

Specimen trees of the two spring plantings were carefully lifted from time to time and the root systems examined. For purposes of comparison, fall-transplanted trees which had remained in the nursery were also lifted.

An examination, on April 11, of a tree planted March 25 showed that no new roots had formed. The numerous new root tips and root hairs which were observed at the time of planting had either disappeared or turned brown in color, indicating that they had probably ceased to function. April 19, or twenty-five days after planting, another tree was lifted. A new root one inch long was observed, as well as several other root tips which were from one-eighth to one-half inch in length. These roots were all near the ends of fibrous roots. No callous formation had taken place. On the same day, a tree transplanted October 30, 1915, was removed for the purpose of comparing its root development with that of the spring-set tree. A very vigorous new root system was observed. The new roots were from one-half to four inches in length and proceeded from the shorter main roots. Eight

roots three-fourths and one and one-half inches long were growing from the end of a root one-eighth inch in diameter. New root tips were forming near the end of all the smaller roots, and, in addition, each root was well supplied with root hairs. This tree, therefore, was well prepared to supply water and food to the expanding leaves, which were at this time approximately three-fourths inch in width. The leaves on the spring-set tree were not quite so far advanced as those planted in autumn.

Examination, on April 22, of a Winesap tree which was transplanted March 29, showed that three new root tips one-eighth inch in length, had formed near the ends of main roots. A few new root hairs were observed. The leaves upon this tree were just unfolding. For comparison, the neighboring tree which was transplanted December 2, 1915, was removed. The new root development was found to be even more extensive than that observed on the trees which were planted October 30. The later planted trees, however, were placed in a soil more favorable for root growth than were the earlier planted trees.

Observations made May 3 on a specimen of the spring-planted trees indicated that the roots were not over two inches in length and were few in number. Since this was nearly forty days after planting, it would appear that root growth was progressing rather slowly as compared with that of autumn set trees.

Very little difference has been observed at this Station between the results of early and late spring planting, providing the trees are equally dormant when planted. Dormant fruit trees from cold storage have been planted out with good results as late as June 3. Trees should be dug from the nursery before their buds start and kept dormant until they can be set in the orchard. The writer has observed no advantage in very early spring setting except that of getting the work out of the way. If the soil is too wet to work well in early spring setting may be delayed, if the trees can be kept dormant.

A METHOD OF HOLDING TREES DORMANT FOR LATE SPRING PLANTING

Most nurserymen have storage facilities in which they are able to hold trees dormant until they are shipped for planting. Once they are received by the orchardist they are usually "heeled-in" unless conditions admit of setting them as soon as they are received. If wet soil or other circumstance delays planting, the trees may put out their leaves while heeled-in. If the trees start growth while heeled-in in the trench they are likely to suffer when transplanted, due to loss of water thru the leaves, before the roots become established.

If it becomes necessary to hold trees in the trench for late spring planting, the writer has found they may quite readily be kept dormant by rehandling as often as the buds show sign of starting into growth. As the buds begin to swell the trees may be lifted from the trench, turned over to expose their opposite sides to the sun, and heeled-in again in the same trench. This lifting and turning and heeling-in usually delays the growth of the buds from ten days to two weeks. If trees are handled in this way as often as is necessary, they may be held dormant for planting until very late spring, when the soil becomes dry and warm enough to induce the roots to start simultaneously with the leaves after they are set.

Since the terminal buds normally start growth more promptly than do the lower lateral buds it is advisable to prune the trees back properly for setting, at the time they are first heeled-in. The more dormant, lateral buds remaining on the shortened branches start new growth slowly. Furthermore, removal of the surplus growth reduces the evaporating surface and saves the trees from undue drying out.

RELATIVE TRANSPIRATION FROM DORMANT BRANCHES OF ESTABLISHED AND TRANS- PLANTED APPLE TREES

Earlier in this bulletin it has been shown that late fall-planted trees made better growth than early fall-planted trees. It was observed that the twigs of trees planted in very early autumn appeared to shrivel slightly, indicating that they dried out somewhat more than trees planted in late autumn.

During the season of 1915-16 Mr. Jesseman, graduate student, previously quoted in this bulletin, made some very interesting observations upon this point under the writer's direction. Mr. Jesseman's discussion of his results follows:

Transpiration takes place from dormant twigs even on the cold days in winter. This loss of water, even tho very small in amount, must be supplied by movement of water upward from the roots of the tree. If sufficient water cannot be supplied desiccation or winter killing results. This winter injury is one of the factors limiting the success of autumn planting in sections of the country where cold drying winds prevail in winter. It is the general opinion that moisture is lost more rapidly during prolonged periods of cold in winter and that water is taken up again by the roots during subsequent warm periods. It is also believed that fall-planted trees experience considerable loss of water before the root system becomes reestablished in the soil, and are likely to be in a weakened condition when growth begins in spring.

In order to shed further light upon these questions, the writer has made moisture determination of dormant twigs from undisturbed and from autumn-transplanted apple trees. Four determinations were made as follows: Before and after a cold period of three days duration; again after several days of rain; and finally, at the beginning of growth in spring. The results of these determinations are given in the following table:

TABLE 26.—MOISTURE CONTENT OF DORMANT BRANCHES FROM UNDISTURBED TREES AND FROM TREES TRANSPLANTED IN AUTUMN

Trees	Percentage of moisture			
	Jan. 16, 1916	Jan. 20, 1916	Jan. 27, 1916	Mar. 27, 1916
Undisturbed	52.74	51.66	52.03	50.73
	50.57	51.26	53.64	52.59
Average	51.65	51.37	52.83	51.67
Transplanted Dec. 7, 1915 ..	50.99	51.24	51.80	48.37
	51.28	51.18	51.74	50.27
Average	51.13	51.23	51.77	49.32
Transplanted Nov. 1, 1915 ...	48.67	-----	-----	-----

The trees from which the data were obtained were three years old and of the Early Harvest variety. They were standing six feet apart in the nursery row, and on December 7 two of them were lifted and immediately replanted in their original positions. Hence the conditions were the same for all these trees except for the disturbance due to transplanting two of them. The soil is heavy clay loam. Twigs in a healthy condition and from the corresponding portions of the different trees were removed for analysis on the dates indicated in Table 26. These were heated in a desiccating oven at a temperature of from 100 to 110 degrees Centigrade until they reached constant weight. The few trees which were transplanted November 1 were cut back at the time of planting and hence afforded material for only one determination.

As will be seen from Table 26, the average percentage of moisture in the twigs of trees under normal conditions on January 15 was 51.65, as compared with 51.13 per cent for the trees transplanted December 7. Thus, trees which had been transplanted over a month contained only 0.52 percent less water than undisturbed trees. It should be noted that just previous to this date the lowest temperatures of the winter occurred; namely -6, -11, -2 degrees F., January 12, 13, and 14, respectively. January 19, after three days of continued cold, when the minimum temperature was 0 degrees and the maximum 32 degrees F., another analysis was made. The undisturbed trees showed a slight loss of water. It is probable that the undisturbed trees showed a larger amount of evaporation because they possessed a larger amount of water when cold weather came on and therefore had more water to lose.

In the interval between January 20 and January 27, temperatures as high as 63 degrees F., and much rain occurred. Analyses made at the close of this period, indicated that the average moisture content of the normal trees

was 52.83 per cent, and of the transplanted trees 51.77 per cent. The former trees gained 1.46 per cent and the latter 0.54 per cent. This appears to confirm the opinion that trees tend to become more turgid during warm periods in winter. Also, that trees whose root systems have been mutilated by transplanting in autumn are not able to recover their turgidity as rapidly as trees which have not been disturbed in this manner.

It might be concluded from the foregoing paragraph that the autumn-planted trees would suffer during the winter a marked deficit in water content. Reference to the table shows that, on March 27, when the buds were beginning to open, the average moisture content of the fall-planted trees was 2.35 per cent lower than that of the undisturbed trees. This deficiency in moisture apparently had no injurious effect upon the trees in question. It is probable that fall-planted trees can withstand a greater loss of water than the above-named amount without serious injury. The following statement by Sorauer" (p. 91) is of interest in this connection: "Freshly transplanted trees and shrubs are more sensitive than the untouched ones; generally speaking, the roots are more sensitive than the stem and branches, owing to their more delicate tissues and the larger percentage of water of the former. The branches of fruit-trees where transplanted in the autumn were less damaged by frost than those which had remained in their original positions."

Such a phenomenon is, in all probability, due to the fact that the branches contained less water, as the transplanting, by damaging the many root tips, consequently stops the growth of the branches, and accelerates the ripening of the wood. Chandler" concluded also that greater concentration of sap which results from usual evaporation of water from trees during the winter would, by lowering the freezing point of their sap, render plants less liable to injury by low winter temperatures.

In addition to the analyses already discussed, the moisture content was determined on January 16, of trees which had been transplanted November 1. It was found to be 48.67 per cent, or 2.46 per cent lower than the average of the trees which had remained in their original position. On the other hand, the average water content of trees planted December 7, or over a month later, was 51.13 per cent, or only 0.52 per cent less than the normal trees. This would seem to indicate that the rate of evaporation was much higher during the month of November than during December and early part of January, as might be expected. While in this comparison the results may have been influenced by the individual variation of the trees, or may be within the limits of experimental error, it is of interest to consider it in connection with the fact brought out earlier in this paper; namely, that apple trees planted in the late fall of 1913 (December 6) at this Station, made much better growth during the next two seasons than similar trees set a month earlier, or November 8, 1913. These two facts, considered together, may be a confirmation of the opinion expressed by Whitten that the high temperature and bright sunlight of this interior climate, which often prevail until late autumn in this section, may serve to keep up the activity and a high rate of evaporation in the early-transplanted tree until late in November. Under such conditions it would undoubtedly be wiser to transplant in late autumn when the functions of the aerial portions of the trees have become practically dormant, and while a sufficient store of heat still remains in the soil to stimulate new root growth, before severe weather of winter.

Part II—Minor Studies Relating to Transplanting

RELATION OF MULCHING TO THE DEVELOPMENT OF FALL-PLANTED APPLE TREES

The opinion is quite general among horticulturists that fruit trees should be mulched when transplanted in autumn. The benefits of a mulch, sometimes suggested, are that it delays freezing of the soil in autumn, giving the roots a longer time in which to heal, callous or make growth; prevents heaving of the soil by alternate freezing and thawing in winter; prevents deep freezing in severe climates, and protects the roots of the trees from drying out in dry climates. Clement¹⁸ advised banking up around fall-transplanted trees with soil and then mulching with manure. Wickson⁵², referring to California conditions, states that "even in localities of light rainfall, if the trees are well mulched early in the winter, irrigation may be unnecessary for the young, deciduous trees." Oskamp⁴⁰ found that the soil beneath a mulch of straw and grass cooled off less quickly in autumn than where clean cultivation was practiced, and that it retained a higher minimum temperature until spring. In spring, however, the soil warmed up less where the mulch was maintained, than where clean cultivation was practiced.

There can be little doubt that a mulch may be beneficial to autumn-transplanted trees in climates where the roots are subject to injury from severe freezing, or in very dry climates where the roots may suffer from lack of soil moisture. A mulch applied in summer may also be beneficial in preventing drying out if a dry hot summer follows fall planting. There is some question, however, as to whether fall and winter mulch is desirable under Missouri conditions, where winter freezing is not severe and where soil moisture is usually adequate, and sometimes excessive, during winter and spring.

The question also arises as to whether a mulch may not even retard growth of the roots, if it is retained in spring, by preventing the soil from warming up rapidly. Even if the mulch is removed in early spring, may not the soil retain water enough to keep the soil cool and delay root action?

In order to throw light on this subject, for Missouri conditions, observations were made in 1914 upon trees mulched and not mulched, which were planted the previous season. The apple trees under observation were Transparent, Grimes, Jonathan, Winesap and Early Harvest. The trees of the former two varieties were two years old and the latter three were one year old when transplanted.

TABLE 27.—GROWTH DURING THE SUMMER OF 1914 OF APPLE TREES MULCHED AT THE TIME OF TRANSPLANTING IN AUTUMN

Variety and date of planting	Diameter when set, inches	Diameter, Aug. 14, 1914, inches	Diameter, Nov. 20, 1914, inches	Amount of length growth, inches
Transparent—				
Nov. 8, 1913.....	32/64	42/64	52/64	237
	20/64	46/64	49/64	208.5
	32/64	45/64	54/64	150
	28/64	43/64	48/64	222
	32/64	42/64	50/64	295
	28/64	35/64	37/64	136.5
	28/64	40/64	41/64	133
	24/64	32/64	37/64	126
	28/64	34/64	39/64	101.5
	28/64	34/64	49/64	173
Average	28/64	39/64	46/64	178.3
Grimes—				
Dec. 6, 1913.....	20/64	29/64	29/64	52
	28/64	38/64	44/64	90
	20/64	28/64	40/64	333
	24/64	34/64	34/64	187
	20/64	37/64	48/64	161
	32/64	37/64	42/64	119
Average	24/64	34/64	40/64	157
Jonathan—				
Nov. 8, 1913.....	18/64	27/64	35/64	171
	8/64	28/64	36/64	339.5
Average	13/64	28/64	36/64	255.2
Winesap—				
Nov. 8, 1913.....	8/64	29/64	41/64	184
	8/64	20/64	22/64	78
	8/64	25/64	36/64	181
	12/64	29/64	38/64	136.5
Average	9/64	26/64	34/64	145.0
Early Harvest—				
Nov. 8, 1913	8/64	26/64	34/64	117
	12/64	26/64	30/64	55
Average	10/64	26/64	32/64	86
Jonathan—				
Dec. 6, 1913	8/64	26/64	34/64	135
	8/64	27/64	34/64	183
Average	8/64	27/64	34/64	159
Winesap—				
Dec. 6, 1913	12/64	35/64	49/64	251
	8/64	31/64	46/64	287
	8/64	29/64	41/64	264
	12/64	30/64	40/64	141
Average	10/64	31/64	44/64	235.7
Early Harvest—				
Dec. 6, 1913	8/64	34/64	39/64	132
	12/64	34/64	40/64	174.0
Average	10/64	34/64	40/64	153.0
Total	572/64	1058/64	1296/64	5553.5
Average	17/64	33/64	40/64	174.0

TABLE 28.—THE GROWTH DURING THE SUMMER OF 1914 OF APPLE TREES NOT MULCHED AT THE TIME OF TRANSPLANTING IN AUTUMN

Variety and date of planting	Diameter when set, inches	Diameter, Aug. 14, 1914, inches	Diameter, Nov. 20, 1914, inches	Amount of length growth, inches
Transparent—				
Nov. 8, 1913	28/64	36/64	45/64	312
	28/64	44/64	52/64	253
	28/64	45/64	55/64	406
	32/64	48/64	41/64	355.5
	32/64	37/64	37/64	166
	28/64	33/64	42/64	120
	24/64	36/64	55/64	136
Average	29/64	40/64	47/64	249.5
Grimes—				
Dec. 6, 1913	16/64	25/64	29/64	74
	28/64	34/64	35/64	149
	32/64	37/64	44/64	191
	20/64	27/64	32/64	171
	20/64	30/64	40/64	111
	28/64	34/64	35/64	110
Average	24/64	31/64	36/64	134.3
Jonathan—				
Nov. 8, 1913	12/64	16/64	44/64	258
	16/64	36/64	45/64	255
Average	14/64	26/64	45/64	257
Winesap—				
Nov. 8, 1913	16/64	32/64	36/64	292
	16/64	28/64	36/64	130.5
	12/64	29/64	40/64	181
Average	15/64	30/64	37/64	201.0
Early Harvest—				
Nov. 8, 1913	12/64	30/64	34/64	173
	20/64	33/64	44/64	162
Average	16/64	32/64	39/64	167.5
Jonathan—				
Dec. 6, 1913	12/64	33/64	43/64	277
	12/64	31/64	45/64	262
Average	12/64	32/64	44/64	169.5
Winesap—				
Dec. 6, 1913	12/64	54/64	44/64	352
	12/64	31/64	45/64	218
Average	12/64	43/64	45/64	285.0
Early Harvest—				
Dec. 6, 1913	12/64	30/64	42/64	92
	20/64	36/64	43/64	193
Average	16/64	33/64	43/64	142.5
Total	528/64	885/64	1083/64	5400.0
Average	20/64	34/64	42/64	207.7

Immediately after planting in the fall, alternate trees in each row were mulched with straw, as shown in previous tables in which the growth of these varieties is recorded. The mulch was allowed to remain about the trees until time to begin spring cultivation, when

it was removed in early April. The trees mulched and not mulched were given similar treatment and clean cultivation during the summer.

The resulting growth of the trees which were mulched and those which were not mulched is recorded in Tables 27 and 28. The mulched trees made a somewhat smaller average increase in diameter of trunk than did the trees which were not mulched. The mulched trees made an average total length growth of twigs amounting to 174 inches and the trees not mulched averaged a length growth of 212.5 inches, or an average of 36.5 inches per tree, which is 21 per cent in favor of the latter.

It is apparent that the mulch was somewhat detrimental rather than beneficial in this instance, apparently due to its retarding the warming of the soil about the roots of the mulched trees, even tho it was removed in early April. In cultivating the soil about the trees, after the mulch was removed, it was evident that more moisture was retained in the soil where the mulch had lain over winter than in the soil about the trees that had no mulch.

There was no visible difference in the time at which growth above ground began on the mulched and unmulched trees. This fact was to be expected as it has been shown repeatedly at this Station and elsewhere that a mulch about the roots of a tree does not retard the spring growth of its buds above the mulch. Spring growth of the buds is governed by the temperature of the twigs and buds themselves and is practically uninfluenced by the temperature of the roots.

Additional trees were reserved for examination as to comparative root growth as influenced by mulching. Specimens were examined from time to time. Roots began to form on mulched and unmulched trees in early January, following fall transplanting. At that time the ground was frozen to a shallow depth beneath the mulch tho not so deep as where no mulch was applied. There was no marked difference in the amount of root growth of mulched and unmulched trees up to the time the mulch was removed in spring. Unfortunately facilities were not available for recording comparative soil temperatures.

The foregoing record, combined with general observations made in other seasons on results due to the presence or absence of a mulch about fall-planted trees, at this Station, indicate that there is no advantage in a winter and spring mulch under Missouri conditions. Whenever there is an abundance of soil moisture in the

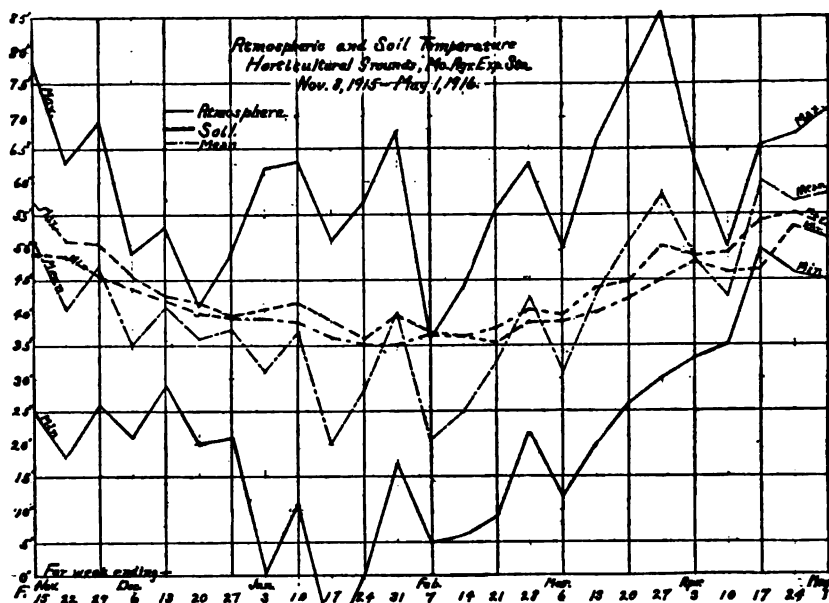
spring the mulch appears to be slightly disadvantageous and in no instance has it proved to be beneficial.

RELATION OF SOIL AND ATMOSPHERIC TEMPERATURES TO FALL AND SPRING PLANTING

The growth of any part of a plant is profoundly influenced by temperature. The soil temperature about the roots and the atmospheric temperature surrounding the twigs and buds must be regarded as important factors in determining the root and twig development of transplanted trees. It has been previously noted in this bulletin that trees transplanted in early autumn, at the Missouri Experiment Station, have not started new root growth ahead of similar trees planted in late autumn or early winter. It has also been noted that trees transplanted in very early spring do not renew their root growth promptly; usually it starts no earlier than on trees planted later in spring. In the case of both early and late spring-planted trees new root growth is usually delayed until the leaves appear. On the other hand, both early and late fall-planted trees begin new root growth after the surface of the earth freezes (usually in early January), and it apparently continues below the frost line during winter and is well advanced when the trees put out their leaves in spring. The new roots of undisturbed trees apparently have no very definite rest period, but may make new growth after the trees shed their leaves in autumn. This growth may continue slowly below the frost line in winter and somewhat rapid new root growth formation may begin in advance of leaf formation. Fall and winter root growth is made well below the surface of the soil; early spring root growth is most marked near the surface, where the soil warms first.

With the hope of throwing some light upon the reasons for the behavior of the trees, a continuous record of soil temperature from November 8, 1915, to May 1, 1916 was made. This record, together with a record of atmospheric temperature, is shown in the accompanying chart. The weather record was obtained from the Columbia, Missouri, office of the United States Weather Bureau. The soil temperature was taken by a Julien P. Freiz & Sons thermograph. The bulb was placed at a depth of fifteen inches, which was the average depth of the lower roots of transplanted trees. The reading of the thermograph was checked by comparison with standard thermometers. The data were taken and the chart prepared by Mr. Jesseman, graduate student in the department.

The chart shows comparative uniformity of soil temperature as compared with extreme fluctuations of the atmospheric temperature. It is of interest to note that at one time the temperature of the air was 47 degrees below that of the soil, while on another occasion it was 45 degrees above the soil temperature at a depth of fifteen inches. Further examination of the chart shows that there was a gradual depression of soil temperature until January 24, when a gradual rise began. The soil temperature during the week ending



November 15 was practically the same as the temperature on May 1. The mean temperature of the air dropped below that of the soil by the first of December and continued so, with one minor exception, until the last of February, when a rapid rise of temperature began.

The weather record shown in the chart, from November 15, 1915, to May 1, 1916, is found to vary but little from the twenty-year average at Columbia, Missouri. While the soil temperature record covers but a single winter, it is probable that it also conforms closely to the seasonal average, since the soil temperature curve is shown to follow a close relation to the mean of the atmospheric temperature. It is known that in exceptional seasons, however, soil at Columbia may freeze to a greater depth than fifteen inches, altho the minimum shown by the chart is 35 degrees at that depth.

These data, considered in connection with the known habits of growth of fruit trees, are of great interest in studying the results of transplanting at different seasons. Young, deciduous fruit trees usually continue their growth in central Missouri until moderately late autumn. The average first killing frost occurs October 15. With the first hard frost the lower leaves begin to fall. By the last of October the leaves are largely shed, or in condition to be stripped and the trees dug. If, however, the trees are allowed to stand in the nursery, a few leaves usually remain green toward the younger tips of the limbs until the middle of November. Cork formation about the lenticels and leaf scars and general ripening of the wood goes on so the twigs cannot be said to have their activity checked sufficiently to be fully in their winter rest before November 15.

If trees are transplanted in early autumn they are still in a condition to transpire and dry out somewhat, during the warm, often dry, sunny days of early November. Reference to the chart shows that on November 15 the maximum air temperature was 78 degrees but that it fell rapidly after that date. That transplanting after the trees are fully ripe and the days become cool gives better results, is shown by the tests at this Station and previously discussed in this bulletin.

It is shown by the chart that soil temperatures remain favorable for root growth long after top growth has ceased and the trees are fully ripe and at rest above ground. The fact that trees transplanted in late fall begin root growth as soon as do those planted earlier in autumn, has previously been shown. It has also been shown that late-planted trees dry out less during the winter. There is no special advantage in early planting since the soil ordinarily does not freeze sufficiently to interfere with the work until about December 10, and new root growth does not usually begin until about the first of January.

In central Missouri, it is probable that the soil attains its maximum store of summer heat in October altho we have no local data by which to prove at what date or what distance this heat extends to its greatest depth. This heat, passing out of the soil, in early winter, apparently stimulates root growth of the trees, very much as mild bottom heat from a hot bed might do, long after the atmosphere is cold enough that the twigs above ground are in their most complete rest. It has been observed repeatedly at the Missouri Experiment Station that the lower roots of fall-transplanted trees begin new root growth, and that cuttings of grapes and other woody plants

begin to callous and often make roots, in early January, after the surface of the soil is closed in by a frozen layer or "frost shell" several inches in thickness. At this time there is usually a considerable period in which the trees or cuttings are very turgid. Evaporation from their parts above ground is apparently reduced, due to the low atmospheric temperature, while they are amply supplied with water from the warmer moist soil surrounding their parts that extend below the frost line. This should not be confused with the fact that the twigs may shrivel somewhat later on if periods of dry cold weather prevail and the soil freezes so deep as to oppose taking in water by the roots.

Apparently there is an accumulation of "bottom heat" below the frost layer, once the layer has formed to a depth of a few inches. It will be observed that there is an upward tendency of the soil temperature curves in the chart, from December 27, to January 10, in marked opposition to the general downward tendency of the curves of the atmospheric minimum and mean. While the soil temperature at this time was about 40 degrees at a depth of fifteen inches, the surface of the soil was frozen to a depth of about four inches, the expanding ice crystals in the surface soil thus forming a tight shell of earth.

Apparently, also, there is a tendency toward the movement of surplus water to the frozen surface layer from the warmer soil immediately below, thus allowing the soil about the roots below the frost line to become more flocculent, when at the same time the frozen surface layer is becoming more impervious by its accumulation of ice formed of the water from below. No very definite data are available with which to substantiate this suggestion, but the following observations seem pertinent.

Often the surface soil is dry enough to work well about trees or cuttings just before it freezes. As it begins to freeze abundant ice crystals appear on the surface, even if the air is relatively dry. Soon a network of ice may cover the ground. This does not occur unless there is a liberal supply of soil moisture below the surface. If the warm weather occurs to thaw the surface soil it is found too wet to work until the entire frost layer thaws so that the accumulation of surface water can drain downward. The action, during the early winter, of heat stored in the soil during the previous summer is well illustrated by the following observation. In cold climates a heavy snowfall may cover the ground in early winter. If the ground is not frozen it may not freeze under the snow during the winter. If

the surface soil is frozen previous to a very heavy snowfall the frost layer may be thawed, from *below*, owing to the influence of the heat below the frost line. If the snowfall covers frozen ground in late winter the soil thaws from *above* with the melting of the snow, while frost may remain below even after spring crops are planted.

If trees are planted in very early spring the soil about their roots is warmed slowly, while the air above warms rapidly. As a result the buds of early spring-planted trees tend to start growth in advance of the roots. If planted in late spring after the soil has become warm, root growth and top growth are more nearly simultaneous, providing the buds are fully dormant when the trees are planted.

RELATION OF WOUNDS TO THE ACTIVITY OF ADJACENT BUDS

It is a matter of common observation that the terminal bud of a branch normally starts growth in spring in advance of the lateral buds lower down. If the terminal bud is removed in pruning back the branch, the buds which remain near the cut end tend to start in advance of those lower on the twig. Insect punctures on the side of the twig often stimulate the growth of the adjacent buds in advance of those more remote from the wound. In forcing twigs into growth in vases of water in the greenhouse during winter, the writer has often observed that the lower bud adjacent to the cut end of a twig may start growth in advance of the others. Uninjured buds near a wound of any kind tend to make an earlier start.

In this connection McDougal³⁹ says "intense mechanical forces which cut, tear or crush the protoplasts or their membranes, exert a stimulating effect upon the neighboring uninjured elements as well as the entire organism in some instances." In the writer's experience, if the wound is made the previous autumn the stimulus appears to be greater than if made shortly before the buds start growth. Trees transplanted in the fall make stronger growth if cut back when transplanted than if the pruning is delayed until spring. The same is also true of trees which are not transplanted. This may be due in part to greater desiccation from the twig surface of unpruned trees and also the fact that there is rapid loss of water from the pruning wound made in spring, before the ducts are closed by the normal process. The belief that it is also due in part to the greater stimulus of wounds made in autumn is supported by the following evidence:

On three separate occasions the writer has grown deciduous fruit trees in greenhouse benches for a period of years. Under these conditions a moist atmosphere and temperature suitable to growing plants was maintained throughout the winter. The trees were not subjected to drying out or to cold weather. The rest period of the trees was shorter than that of trees subjected to open field conditions. Twigs were pruned back at the time they shed their leaves in December and similar twigs were pruned just before growth was resumed in late February or March. A part of the wounds were paraffined as soon as they were cut to prevent drying out. Stronger average growth was made by the buds adjacent to wounds made at the beginning of the rest period. Similar results have been secured in the case of a still larger number of trees, grown in open ground, even in seasons when winter desiccation was least marked.

Typical results, showing the relation of wounds to growth of the adjacent buds were secured by Mr. Jesseman. The following quotation from his discussion is of interest, in connection with Plate II.

The effect of wounding upon the activity of dormant buds may be shown more directly by the following experiment, in which a wound is made through the cortex closely adjacent to the buds themselves.

The material used in this experiment was one-year-old wood from a Delicious apple tree. These branches were removed February 22, 1916, while the buds were still dormant. They were cut into equal lengths and divided into seven groups of six twigs each. The character of the wound made on half of the twigs in each group was an incision with a knife through the cortex across the axis of the twig. On the other half a small notch about one-sixth inch wide was made, removing a portion of the cortex. Alternate buds were wounded. The position of the wounds was varied for each group, as follows: No. 1, below the bud; No. 2, above the bud; No. 3, above and below the bud; No. 4, lateral and longitudinal on one side only; No. 5, same as No. 4 on both sides of bud. Twigs in No. 6 were pruned to different lengths, and those in group No. 7 were checks.

The accompanying photograph [Plate II] taken March 7 shows two average specimens from each group. It will be noticed that the wound was not effective in all cases in stimulating a bud into making greater growth than the adjacent unwounded buds. These results are influenced to some extent by the variation in the buds.

It was found by counting the number of buds which had burst that the second treatment, or wounding above the bud, appeared to afford the greatest stimulus. Wounding above and below the buds was effective in a nearly equal number of cases. A lateral wound on one side only was apparently less effective than transverse wounds above or below the bud, with the exception of the excessive growth of the bud near the terminal of III, *a* [Plate II]. [In the same figure] IV, *b* shows that notching on both sides was too severe

a treatment. The buds on the twigs in this group dried up before they had started appreciably. It will be noted that whether a branch is pruned short or long that the outermost bud makes an earlier and more vigorous growth than the remaining buds on the branch. The normal twigs in Group 7 indicate that the terminal buds are much in advance of the laterals, and that the latter started quite uniformly. The relative effect of two forms of wounds was noticeable. The notched buds seemed to start earlier, but they soon appeared to suffer from desiccation. A simple knife-cut thru the cortex was sufficient to produce marked results.

These results show, therefore, that dormant lateral buds may be stimulated into abnormally early growth by means of a wound in close proximity of the bud. The greatest stimulus is afforded by an incision thru the cortex immediately above the bud. Lateral wounding is a less effective stimulus. Removing a portion of the cortex in making a notch may be too severe a wound, causing loss of water from the bud.

These results are in accord with statements made by Gaucher²², Gressents²³, Lauche²⁴, and Lucas²⁵. Weber²⁶, in an experiment on shortening the rest period of shoots, found that injured buds in almost every case preceded in opening and rapidly outgrew untreated buds on the same sprout.

The practical suggestions might be made in connection with this experiment that it may be advisable to prune back in autumn trees that are to be transplanted in spring; also that branching may be induced on poorly headed trees."

THE TIME TO PRUNE TRANSPLANTED TREES

The time to prune transplanted trees, and young trees not to be transplanted, has been much discussed. Early spring has been most generally recommended for pruning. It is the usual custom to prune back the branches of young trees when they are transplanted. Some writers have recommended delaying pruning back fall transplanted trees until spring. The precaution often urged against cutting back the branches in the fall is that the tree loses too much moisture thru the cut surfaces of the twigs. Fear has been expressed that the cut-back branches will dry out sufficiently to kill back badly during winter. The question naturally arises as to whether more water will be lost thru the wounds of the cut twigs than would be transpired from the branches were they left intact.

In order to answer this question for Missouri conditions, general observations have been made on young trees pruned at different seasons at the Missouri Experiment Station in the last twenty years. The results uniformly indicate that better growth results if the branches are cut back in the fall. This holds true for young trees generally, whether they are transplanted in the fall or spring or whether they are not transplanted.

Mr. Ed. Kemper, a skillful grape propagator and grower of Hermann, Missouri became interested in the writer's observations on this subject, when he was a student at the University of Missouri. He has since assured the writer that grapes, especially, make better growth if pruned back in the fall. He sets his cuttings in autumn as soon as the vines shed their leaves and thereby successfully roots Norton, Cynthiana and other varieties found to root with difficulty if the cuttings are made and set in early spring. He further says that one-year-old grapes, designed to stand a second year in the nursery, make much better growth if pruned back in the fall; also that bearing grape vines make stronger growth if pruned in autumn as soon as their leaves are shed. He emphasizes this particularly in the case of varieties that tend to make poor renewal growth from the lower spurs. These, according to his experience, make better growth from renewal spurs if pruned in autumn.

Tests made at the Missouri Experiment Station in 1900 and 1901 are typical of the results secured generally with apples. The details of this season's work shown in Tables 29, 30 and 31, were carried out by Mr. W. L. Howard, who at that time was a graduate student in this department.

From the tables it will be seen that there was very little difference between the water content at the periods when tests were made of apple trees transplanted in late fall and those which were not transplanted. The fact is also indicated that the trees whose branches were pruned back in late autumn contained, on the average, slightly more water than those which retained their branches. While this difference is not great it at least indicates that the pruned branches did not suffer from drying out thru the wounds, but that on the contrary the pruned trees dried out slightly less than did those which were not pruned.

TABLE 29.—SHOWING THE AMOUNT OF WATER ON MARCH 6, 1901, IN TREES TRANSPLANTED AND NOT TRANSPLANTED, AND PRUNED AND NOT PRUNED

Portion of tree	Two-year-old Ben Davis				One-year-old Ben Davis			
	Transplanted Nov. 19, 1900		Not Transplanted		Transplanted Nov. 19, 1900		Not Transplanted	
	Lot 1 Fall pruned	Lot 2 Not pruned	Lot 3 Fall pruned	Lot 4 Not pruned	Lot 5 Fall pruned	Lot 6 Not pruned	Lot 7 Fall pruned	Lot 8 Not pruned
Branches	46.25	47.21	47.19	50.04	45.51	44.44	.....	.....
Trunk	42.73	42.08	43.12	46.49	57.93	56.40	47.48	50.00
Roots	50.00	48.82	53.76	52.84	54.77	52.80	53.92	59.15
Average for trunks and branches.....	44.49	44.64	45.15	48.26	52.72	50.42	47.48	50.00
Average for whole trees.....	46.32	46.03	48.02	47.12	52.73	51.21	50.70	36.38

Portion of tree	One-year-old Jonathan				One-year-old seedling peach			
	Transplanted Nov. 19, 1900		Not Transplanted		Transplanted Nov. 19, 1900		Not Transplanted	
	Lot 9 Fall pruned	Lot 10 Not pruned	Lot 11 Fall pruned	Lot 12 Not pruned	Lot 13 Fall pruned	Lot 14 Not pruned	Lot 15 Fall pruned	Lot 16 Not pruned
Branches	44.23	33.38	45.69	40.00	42.23	41.88	44.70	45.71
Trunk	46.30	53.26	.....	42.35	.....	41.77	.....	43.39
Roots	56.56	49.06	58.86	56.00	52.31	55.45	59.75	51.14
Average for trunks and branches.....	45.26	43.32	45.69	41.17	42.23	41.81	44.70	44.55
Average for whole tree.....	49.00	45.23	52.27	46.11	47.27	46.36	52.22	47.75

TABLE 30.—SHOWING THE AMOUNT OF WATER ON APRIL 6, 1901, IN TREES TRANSPLANTED AND NOT TRANSPLANTED, PRUNED AND NOT PRUNED

Portion of tree	Two-year-old Ben Davis				One-year-old Ben Davis			
	Transplanted Nov. 19, 1900		Not Transplanted		Transplanted Nov. 19, 1900		Not Transplanted	
	Lot 1 Fall pruned	Lot 2 Not pruned	Lot 3 Fall pruned	Lot 4 Not pruned	Lot 5 Fall pruned	Lot 6 Not pruned	Lot 7 Fall pruned	Lot 8 Not pruned
Branches	47.80	49.60	49.38	51.80	48.80	50.38	.....	52.31
Trunk .....	.....	42.21	48.61	48.46	46.15	47.20	47.20	49.60
Roots	55.52	50.54	53.23	55.29	52.40	58.64	56.06	57.50
Average for trunks and branches.....	47.80	45.90	48.99	50.13	47.47	48.79	47.20	50.95
Average for whole trees.....	51.66	47.45	50.41	51.85	49.11	52.07	51.63	53.13

Portion of tree	One-year-old Jonathan				One-year-old seedling peach			
	Transplanted Nov. 19, 1900		Not Transplanted		Transplanted Nov. 19, 1900		Not Transplanted	
	Lot 9 Fall pruned	Lot 10 Not pruned	Lot 11 Fall pruned	Lot 12 Not pruned	Lot 13 Fall pruned	Lot 14 Not pruned	Lot 15 Fall pruned	Lot 16 Not pruned
Branches	48.97	48.05	48.07	49.41	46.15	48.24	50.00	50.12
Trunk	45.63	41.54	47.61	47.05	46.35	46.87	46.85	44.60
Roots	51.53	55.00	56.14	58.05	56.26	58.87	55.26	59.19
Average for trunks and branches.....	47.30	44.79	47.84	48.23	46.25	47.55	48.42	47.36
Average for whole trees.....	48.71	48.20	50.61	51.50	49.59	51.33	50.70	51.63

TABLE 31.—SHOWING THE AMOUNT OF WATER ON APRIL 22, 1901, IN TREES
TRANSPLANTED AND NOT TRANSPLANTED, PRUNED AND NOT PRUNED

Portion of tree	Two-year-old Ben Davis				Two-year-old Ben Davis			
	Transplanted Nov. 19, 1900		Not Transplanted		Nov. 19, 1900 Transplanted		Not Transplanted	
	Lot 1 Fall pruned	Lot 2 Not pruned	Lot 3 Fall pruned	Lot 4 Not pruned	Lot 5 Fall pruned	Lot 6 Not pruned	Lot 7 Fall pruned	Lot 8 Not pruned
Branches	49.35	45.92	53.75	53.64	53.19	50.00	52.50	50.00
Trunk	49.05	46.16	50.24	50.00	48.17	46.96	52.80	53.16
Roots	49.70	50.34	-----	55.80	52.68	56.73	43.91	56.41
Average for trunks and branches.....	49.20	46.04	51.99	51.82	50.68	48.48	52.65	51.58
Average for whole tree.....	49.37	47.47	51.99	53.15	51.35	51.23	49.74	53.19

Portion of tree	One-year-old Jonathan				One-year-old Seedling peach			
	Transplanted Nov. 19, 1900		Not Transplanted		Transplanted Nov. 19, 1900		Not Transplanted	
	Lot 9 Fall pruned	Lot 10 Not pruned	Lot 11 Fall pruned	Lot 12 Not pruned	Lot 13 Fall pruned	Lot 14 Not pruned	Lot 15 Fall pruned	Lot 16 Not pruned
Branches	52.17	55.55	58.33	55.55	-----	-----	-----	-----
Trunk	46.55	49.42	52.77	50.00	44.51	50.00	51.76	47.36
Roots	53.44	60.00	59.39	59.09	53.70	49.84	59.95	58.76
Average for trunks and branches.....	49.36	52.48	55.50	52.77	-----	-----	-----	-----
Average for whole tree.....	50.72	54.99	56.83	54.88	49.20	49.92	55.85	53.06

An additional test for the amount of water evaporated from trees pruned and not pruned was made as follows: On November 12, 1900, well-branched, two-year-old apple trees were dug from the

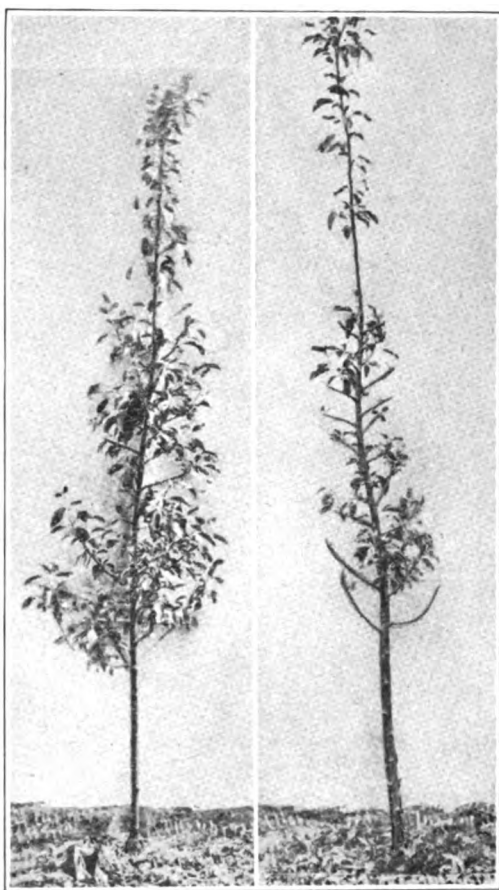


PLATE III.—Average difference in growth on May 15, 1901, of Ben Davis apple trees planted and pruned back on November 19, 1900 (left) ; and planted November 19, 1900, but pruned back in early April, 1901 (right).

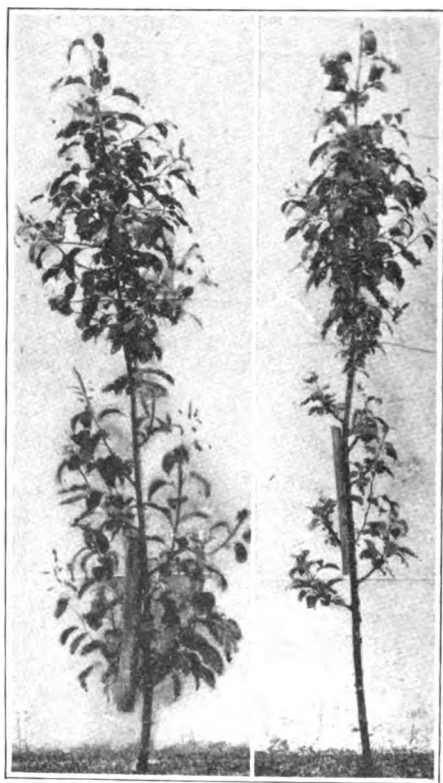


PLATE IV.—The greater growth on May 15, 1901, of side branches pruned back November 19, 1900, and those pruned back in early April, 1901; either tree transplanted. The central stems not cut back made more growth on trees which had side branches pruned in the fall.

nursery and their roots placed in glass museum jars with the tops of the trees extending above the jars. The jars were then sealed above the water, around the trunks of the trees, to prevent evaporation except thru the tops of the trees which grew normally above the ground. One-half the number of trees were pruned and the other half retained their branches. The trees and jars were then placed so as to leave the tops of the trees exposed to outside air during the fall and winter, the jars containing their roots in water being protected from freezing. Each jar, with the trees and water contained, was weighed daily in order to determine the relative weight of water lost by evaporation thru the pruned and unpruned trees.

For the first few days slightly more water was evaporated from the pruned trees, as indicated by their slightly more rapidly diminishing weight. At the end of ten days the trees which were not pruned began to diminish in weight the more rapidly. This indicated that water was lost thru the cut surfaces somewhat more rapidly, at first, until the wounds were closed. As soon as the cuts at the ends of the pruned branches had a little time for their ducts to become plugged in the normal way the unpruned trees lost the greater quantity of water.

While these determinations did not show any very significant difference in the amount of water evaporated from fall-pruned apple trees and those which were not pruned, the following spring growth of the trees set in the orchard did show a marked difference in favor of fall pruning. Plate III shows the average difference, on May 15, 1901 of the trees transplanted, and pruned back on November 19, 1900 and pruned back in early April, 1901. The difference in the growth of the trees showed emphatically that fall-transplanted trees should be pruned at the time they are transplanted.

The advantage of fall pruning over spring pruning was quite as emphatically shown in the case of the apple trees which were not transplanted. Plate IV shows the corresponding growth on May 15, 1901, of representative trees, pruned November 19, 1900, and in early April, 1901.

Attention is called to the fact that the central stem of each tree was left intact, instead of cutting it back, as would be done in shaping trees for an orchard. Growth from the main stems which were not cut back was greater on the trees which had their lateral branches pruned in fall, than on those which were pruned in spring. The greater growth made by fall-pruned trees may be due in part to the greater stimulus of wounds made in the fall as compared with those made in spring. Also, it may in part be accounted for by the

fact that the cuts made in the fall do not lose water in spring when growth begins, while those made in spring lose water and reduce the turgidity of the tree as growth is about to be resumed.

Peach trees pruned in the fall dried out to about the same degree as those which retained their branches during winter. This was true of trees whether or not they were transplanted. Fall transplanting of the peach has proved so unsuccessful in this section that it is recommended that peach trees be transplanted in the spring and pruned back as soon as they are set.

THE DEPTH TO PLANT

The character of the soil and climate of a region should no doubt govern the depth to which the roots of a fruit tree should be set. For most sections it is generally recommended that the roots be set a little deeper than they stood in the nursery. Very deep planting has been emphasized in the prairie states of the northwest, where there is danger of root injury by severe winters. Deep planting is also preferred in the plains where winter desiccation is marked and where rainfall is very limited. No doubt the roots should be set deeper in loose, sandy soils than in heavier soils. Most Missouri growers of long experience advocate setting a little deeper than the trees stood in the nursery. Many who have had limited experience set their trees much deeper than this, with the idea that the trees will stand straighter and firmer and that the roots are thus secured against drying out.

At this Station shallow planting has given better results than deep planting. This point has been repeatedly tested in different years and the results of deep and shallow planting have also been observed in many of the orchards of the state. The results indicate that a majority of the trees set in the state are planted too deep. Deep set roots, especially if spring planted, start growth slowly. The trees usually sway in the wind until a funnel-shaped cavity is formed in the moist soil around the base of the trunk. Borers enter the trunk below ground more readily where such a cavity is formed than in shallow planted trees around which a dust mulch may be retained in close contact with the base of the trunk. Mice find shelter in the soil cavity about a deep-set tree and often girdle it. They rarely girdle trees where the soil is bare and settled in winter, so as to afford no shelter about the base of the trunk. "Root rot" occurs much more frequently in trees set deep.

If trees are set in autumn they may be set an inch or so deeper than they stood in the nursery. The soil at this season is aired and warmed to a greater depth. New root growth starts, in early winter, on the lower roots which become established for early spring growth. If trees are transplanted in spring they should be set no deeper than they stood in the nursery. If the soil is heavy, spring-set trees should stand a little shallower than they stood in the nursery. In the case of spring-set trees, new root growth starts first on the roots nearest the surface of the soil, which is better aired and which warms up first.

In order to stand straight and firm a newly set tree depends largely upon speedy, new root growth to anchor it in the soil.

PROPER ORIENTATION OF THE TREES

In the central west fruit trees tend to lean more or less to the northeast. This is particularly marked in prairie districts. It is also more marked in some varieties of trees than in others. This tendency is largely established while the tree is young, or during the first few years after it is planted in the orchard.

The tendency of fruit trees to lean toward the northeast is due apparently to two causes: The fact that the prevailing winds are from the southwest during the growing season, and the fact that the tissues of the southwest side of the tree tend to "scald" more or less, due to extreme fluctuations of temperature of the sunny side of the tree, especially in late winter and early spring.

Sunscauld, on the southwest sides of the trees in this section has been supposed to occur in summer due to the influence of the hot sun and dry southwest winds during the heat of the summer. That it occurs in late winter has been shown by observations covering a series of years at the Missouri Experiment Station.

In the winter of 1896-7 it was found that the tissues, under the bark, may rise to a temperature of 25 degrees Fah. above atmospheric temperature on sunny days in late winter; also that the tissues on the shady side of the tree remain at atmospheric temperature, or a degree or two lower. These comparative temperatures were secured by inserting thermometers into the sap wood of the opposite sides of the tree. The thermometer bulbs were inserted downward a distance of about two inches below the entrance of the drill holes in which they were placed, the thermometer stems extending upward as nearly parallel with the trunk of the tree as possible.

While the south side of the tree was warmed much above atmospheric temperature during bright sunlight, it cooled rapidly to atmospheric temperature when the rays of the sun were excluded. As an example, on one day in February the atmospheric temperature registered 32 degrees Fah., or freezing, at 1:00 P. M.; the temperature of the shady side of the tree 31 degrees, or one degree colder than the air. The sunny side of the tree showed a temperature of 67 degrees, or 35 degrees above that of the atmosphere. At sunset the temperature of both sides of the tree corresponded to the atmospheric temperature and during the night the atmospheric and tree temperatures were lowered to -12 degrees.

The fluctuations of day temperatures of the south side of the tree were most marked on cold, clear sunny days, when the roots of the tree were frozen, so water could not be taken up by the roots to cool the trunk. Examinations showed that the cells of the south side of the tree trunk were injured by the fluctuations of temperature between day and night.

Similar temperature studies made during the hot weather of summer, showed no essential difference between the temperature of the opposite sides of the tree trunks, but the tree temperatures usually registered 10 degrees to 12 degrees lower than the atmospheric temperature on hot days. This was no doubt due to the cooling of the trunk of the tree by water brought up from below when evaporation from the leaves was rapid.

That the temperature of the tree is lowered by evaporation on hot summer days, is further shown by the following observation. On a hot day in July the atmosphere registered a temperature of 102 degrees. The temperature of the young tree trunk was 90 degrees, just beneath the growing layer. The leaves were then removed from the tree to reduce evaporation. The temperature of the tree soon rose to 103 degrees, or one degree above atmosphere.

'Shading the sunny side of a tree trunk or covering it with lime white-wash reflects the rays of the sun, thus enabling the trunk to remain at atmospheric temperature, or a little below, and avoid sunscald.

This injury to the tissues, to the sunny side of a tree in winter, combined with the prevailing southwest winds, accounts for the fact that young trees make stronger growth on the northeast side and tend to lean toward the northeast during the growing season.

The tendency of young trees to lean toward the northeast may be largely avoided by proper orientation of the tree when it is set

in the orchard. No matter how symmetrical the young tree may appear, it will be found to possess a "heavy" side. One side has a heavier growth. This may be influenced by the sunlight or by the relation of the tree to its neighbors, growing in the nursery row. The pith is not generally in the center of the stem due to unequal thickness of the growing layers on the opposite sides. The roots, branches and tissue development are heavier on one side than on the other.

In planting the tree the heavier side should be set toward the southwest in this interior section. To orient the tree, it should be caught so it will balance, and come to rest, across the palm of the hand. Its heavy side will turn toward the palm. That side should face the southwest in setting. It will be found that the tree will resist bending toward the northeast.

SETTING THE ROOTS IN THE SOIL

The holes which are to receive the roots of fruit trees should be dug just deep and broad enough to accommodate the natural spread of the roots. This general statement is based upon observation of the growth of trees in various soil formations in the state and in which various soil treatments have been tested. The questions of digging larger holes, and of shattering the subsoil with dynamite below the bottom of the tree, have been given attention.

On all well-drained, typical fruit soils, deep plowing, thoro harrowing, and digging the holes of sufficient size to accommodate the roots has proved to be the only treatment necessary to secure the maximum growth of trees. Digging large holes or dynamiting the subsoil has not resulted in any advantage to the trees in such soils. Where trees have been set in sod, as in a lawn, or where replanting has been done between established trees in an orchard, the newly set trees have made much better growth if the holes were dug deep enough and broad enough to kill back the competing roots of the surrounding grass or trees to a distance of several feet. It has been found difficult to get replants in an established orchard to live unless the holes were dug about eighteen inches deep and at least four or five feet wide. This gives opportunity for the replant to become established before the roots of the surrounding trees grow in and compete with the replanted tree.

In doing this work the writer has found that the roots of established fruit trees spread laterally to a much greater distance than

do their branches. Often the roots of the older trees permeate the soil prepared for the replant before the end of the first season. This emphasizes the need of frequently cutting back the roots of the surrounding trees while tilling about the replant until it becomes well established.

In 1914, the use of dynamite to shatter the subsoil was tested on the horticultural grounds at Columbia. This soil is a moderately heavy loam. The dark surface loam is about fifteen inches deep and is underlaid with a heavy, clay subsoil, which becomes more and more impervious, to a depth of twenty feet. The soil and subsoil are too heavy to be well adapted to fruit trees, altho orchards on it have proved fairly profitable if well managed. Apple trees were set, part of the rows having the holes dug just deep enough to accommodate the roots. The alternate rows were set after shattering the subsoil with dynamite below each tree hole to depths varying from four to five feet. The work was done when the subsoil was dry enough to work well.

The first season the trees where dynamite was not used made better growth. Water aparently collected, as in a jug, in the dynamited pockets and did not drain out well below. In three subsequent years no difference could be observed in the growth of the trees where dynamite was or was not used. Each year a study of the root growth of a few of the trees has been made. There is no evidence that the use of dynamite has either favored or opposed root growth. Evidently there is no advantage in loosening a pocket in subsoil so thick that it cannot be shattered deep enough to afford drainage into a porous layer below.

In one region of the state occurs deep, red, clay loam and subsoil mixed with enough sand to give good under drainage. This formation has proved to be an excellent fruit soil except in certain areas in which occurs a layer of pale gray hardpan twelve to eighteen inches thick and lying twelve to twenty inches below the surface. Below this hardpan layer the red clay subsoil is sandy and porous to a good depth. Shattering this layer of hardpan with dynamite under each tree hole has resulted in far better growth of fruit trees. In this case good under drainage is secured once the hardpan is broken thru.

In setting, the soil should be tramped firmly about the roots from the bottom of the hole upward, and an inch of loose soil spread over the tramped surface to prevent the soil from baking and drying out. Much of the mortality of fruit trees is due to bending the roots and failure to compact the soil about the roots in planting.

The roots should be set so as to stand in their normal position. Avoid twisting or bending them. Bending a main root greatly lessens its capacity to take up water and prevents its making normal growth. The roots may be kept in their normal position and the soil compacted about them by observing the following suggestions: Shake the tree vigorously with one hand while the earth is being shaken from the shovel with the other hand. In this way the soil sifts among the roots instead of bending them down, as will be the case if the soil is scraped into the hole in masses. Each layer of soil shaken in should be tramped firmly, from the bottom of the hole upward. It is impossible properly to compact the soil if the hole is filled before it is tramped.

SHAPING THE TREE AT TIME OF TRANSPLANTING

Since 1895, the writer has put out many plantings of young trees to test methods of shaping, ranging from the Stringfellow system, in which the tree is reduced to a short trunk or stub above ground and a single tap root below, to no pruning of either top or root. An intermediate degree of pruning, the severity differing with the species, has given best results under central Missouri conditions. The following suggestions are based upon these results.

The root system of the tree should be pruned just before setting. The tap root should be preserved. The main lateral roots should be shortened to about six inches in length. The small, fibrous roots should be pruned off. This is very important, since if they remain intact they are an incumbrance to the tree. These fibrous roots not only die, for the most part, but they prevent getting the soil in close contact with the essential, larger roots. As trees are ordinarily handled the small fibrous roots dry out and die before the tree is set. They coil more or less around the larger roots like a mass of curled hair. Even if the tree can be dug and planted immediately, the fibrous roots cannot be depended upon to start new growth unless a mass of moist soil can be moved with the roots so as not to disturb the fibrous roots in the soil. Even the naked fibrous roots, if not dried out, are bent so much in setting that they cannot function.

If a main root is more than six or eight inches long it should be shortened. Long roots cannot well be set without bending. A bent or twisted root does not function so well as a shorter root which lies in its normal position. If the end of an essential root has a ragged wound it should be cut back to fresh, healthy tissue, with

a clean, smooth cut. If, however, the end of an essential root has calloused and is healthy it should not be cut, unless the root is too long to plant without bending. Many observations made at this Station since 1895, show that new root growth starts, for the most part, from the sides of the larger main roots where they come in close contact with thoroly settled soil. The small, fibrous roots die unless a large ball of earth is moved with the tree.

The top of the young tree should be pruned as soon as it is set. Experiments recorded elsewhere in this bulletin show that trees make better growth if pruned in the fall as soon as their leaves are shed, regardless of when they are transplanted. Where trees are shipped from a nursery this may not be practicable.

Pruning the newly set tree is primarily for the purpose of reducing the evaporating surface of the tree until new root growth becomes established to supply adequate water. Incidentally, also, it may serve in starting a proper framework, or branching system. The degree of pruning which is desirable differs with the species. Trees like the peach, which start new branches readily from the central trunk but the twigs of which tend to dry out badly, should be cut back most severely. Trees like the sour cherry, which does not start growth readily from the dormant buds on the older parts but which makes its new growth from the active buds near the terminals of its branches, should be pruned least.

After careful study the different species are arranged in the following order, from those which should be pruned most to those which should be pruned least, at the time of transplanting: Peach, nectarine, Japanese plum, apricot, pear, apple, European plum, American plum, and sour cherry.

The peach should be pruned to a single whip by removing the side branches and shortening the main stem to two or three feet in height. The nectarine and Japanese plum should be pruned in a similar way, except that the latter may retain stubs, a few inches long, of three to five main limbs if the branches are large and well established. These species start new growth most readily from the main trunk or the base of the limbs.

The pear and apple should be cut back to a medium degree. The side branches should be cut back so as to reduce them one-half to three-fourths. The central stem should be shortened. At the end of the first season's growth the permanent framework may be established by removing all but from three to five well distributed, outward spreading limbs to secure an open center. If the tree is large,

so permanent limbs may be chosen at the time of transplanting, this permanent framework may be established then. If the tree is a one-year-old whip having no branches it should be shortened to a height of about two and one-half or three feet, with the view to securing a good branching system below the point of cutting back.

The American plum should be cut back somewhat less severely than the apple. If the tree is well branched three or four main limbs may be left intact to form a permanent head and the remaining stem and branches removed. The side branches remaining may be shortened one-third to one-half.

The sour cherry should not have its permanent branches cut back, as it starts new growth most readily from the larger, active buds at the terminals. Three to five main limbs should be chosen for the permanent framework and the remaining limbs and central stem should be removed. The limbs which remain should have their terminals left intact.

PROTECT YOUNG TREE ROOTS FROM FREEZING AND DRYING

The roots of young, dormant fruit trees are easily killed by freezing. The roots will not endure the low temperatures to which the tops may be exposed without injury. The writer's attention was first called to this matter by the following incident:

Two-year-old apple trees were sent to this department in June from an adjacent state, with the statement that they had been held dormant during the winter in cold storage. There was no indication of injury when they came out of storage as the bark and limbs were fresh and bright and the wood of the stem and twigs was of normal color, showing no discoloration such as results from winter injury. Nevertheless, when these storage trees were planted in various orchards they failed to grow. They continued to look perfectly healthy for a time, but remained dormant, and after some weeks began to shrivel and die without having pushed their buds into growth. An examination of the trees sent for the purpose revealed the fact that there was no indication of injury to their buds, branches or trunks. An examination of the roots, however, showed that the inner bark and growing layer was dead and the wood so brown as to show complete winter killing of the root systems. Evidently the roots had been killed by a temperature not low enough to injure the tops.

On several occasions trees have been received for examination, after freezing during shipment. Frequently the roots have been found killed by freezing when the tops were uninjured. As a result tests have been made to determine if possible at what temperature the roots of various species of fruit trees are killed.

As a result of these tests it appears that roots of dormant peaches are killed at about 26 degrees or 27 degrees, pears and apples at about 24 degrees to 26 degrees, and American plums at about 22 degrees Fah. They may be injured more or less by a somewhat higher temperature if exposure is prolonged. None of the roots of fruit trees tested have endured ten degrees below the freezing point of water for any great length of time without being killed.

No doubt the temperature which the roots safely endure varies somewhat with their maturity and the suddenness with which the temperature is lowered. The roots may adapt themselves somewhat to low winter temperatures much as the tops of the trees, but to a less degree. Large roots laid bare by tillage or by erosion in summer often adapt so as to endure the subsequent winter without injury.

It is apparent, however, that the roots of young, dormant fruit trees are far more liable to injury from freezing than heretofore has been recognized and that care should be exercised to protect them from freezing while being handled.

It is a fact generally recognized that trees are easily injured if the roots are allowed to dry out in handling. Apparently, however, this is not always sufficiently borne in mind. The fact that the roots may be handled without cover for a time in a moist packing shed, or in the field during a moist still day, should not encourage the belief that exposure to winds and a dry air may not speedily result in injury. In planting large orchard areas the trees are frequently distributed ahead of the planters where the roots are exposed to the drying influence of sun and wind until they are injured.

At the Missouri Experiment Station tests have been made to determine the amount of injury to the roots occasioned by different periods of exposure under various conditions. Trees were dug from the nursery, on the horticultural grounds, where they could be handled without previous handling, shipping or exposure. A part of the trees, in each instance, were dug and reset as quickly as possible in adjacent ground. Corresponding trees, at each planting were dug and allowed to lie on the ground for various periods of exposure before planting. Tests were made, at different times, when

the atmospheric conditions varied from dry, windy days to still days when the air was humid and the sun overcast with clouds.

On dry, sunny, windy days exposure of the roots for fifteen minutes caused injury, evidenced by the fact that the trees so exposed made less growth than did those which were planted as soon as they were dug. On a day of partial sunshine, with no wind and of fairly high humidity, exposure for thirty minutes did not result in evident injury. Trees exposed for a longer time under these conditions were visibly injured, as was apparent from the poorer growth which they subsequently made. Trees exposed under the same conditions for one hour were so much injured that a majority of them died. On a cloudy day, with sufficient mist to indicate a saturated atmosphere, trees were exposed for two hours without evidence of injury.

Trees have been kept in an unheated room in the basement of the horticulture building, in an atmosphere kept saturated by means of jets of water sprayed into the air, with no packing about their roots, thruout the winter. The roots were not visibly injured. The branches, however, pushed out excrescences of adventitious tissue about their lenticels which appeared like the beginning of aerial root growth. These trees made only moderately satisfactory growth when planted in the spring, their spongy twigs shriveling somewhat before they adapted themselves to field conditions and growth began.

The roots of fruit trees must, of necessity, be exposed more or less in digging, baling and shipping from the nursery. After they are received they must be subjected to additional exposure before they are set in the ground. Since exposure of freshly dug trees for fifteen minutes, if the day is dry and windy, and for more than thirty minutes on an average spring day results in injury to the roots, it is safe to advise that all possible care be exercised to avoid unnecessary exposure in planting.

TRANSPLANTING GARDEN VEGETABLES

Certain garden vegetables such as the tomato, cabbage, cauliflower, pepper, eggplant and sweet potato are usually started in a hot bed or cold frame and later transplanted to an open field.

Often these vegetables are transplanted with less assurance of success in the continental climate of the central west than in the maritime climate of the coast states. In the west, weather changes are often marked by extremes with reference to temperature and

moisture, which are essential factors governing successful transplanting. Transplanted vegetables are sometimes subjected to injury or death by late spring frosts or by dry, windy weather following transplanting.

Injury by late frosts in part may be obviated by covering the plants during a cold spell with newspapers, inverted boxes or other covers or even with dry soil, if the form of the plants admits. Injury from drouth and dry winds may be lessened, tho not fully overcome, by watering or shading the plants until their roots are established. These are expedients which entail labor and expense. Any more feasible method of preventing injury becomes of interest.

At the Missouri Experiment Station it has been found that the condition of the plant, as influenced by the surroundings in which it is grown, may greatly favor or oppose success in transplanting. Plants grown in a sandy soil, low in plant food, watered sparingly and ventilated freely are far less subject to injury from dry or cold weather than are succulent plants, grown rapidly under opposite conditions.

The usual custom is to grow these plants as rapidly as they can be forced, in a rich soil, with abundant bottom heat and with copious watering and a moist atmosphere. Plants thus grown are large and succulent, and luxuriant so long as they remain in the forcing bed. The plants are usually "hardened off" by withholding water for a day or two, until the plants wilt slightly. They are then copiously watered and transplanted as soon as they become turgid.

The writer has found by experience covering a number of years, that smaller plants grown under conditions less favorable to succulent development transplant with less loss. In 1915, tomato plants were grown in a thin, sandy seedbed, watered sparingly and ventilated abundantly. By the middle of May they averaged eight inches in height, had thick, stout, hard, woody stems and short joints. Their leaves were relatively small but abundant. They had enormously developed, fibrous root systems, due to thin loose soil and scanty water.

From the same seed packet other plants were grown in the usual rich potting soil, abundantly watered and not ventilated enough to reduce rapid growth. By the middle of May they were eighteen inches high, had succulent stems, large leaves and longer joints altho they were not what the gardener would call "stringy." They were in bloom. They were repotted often enough to avoid checking their growth.

Both lots were transplanted to the field the middle of May. The soil had been kept in fine condition but the weather was dry, hot and windy following the transplanting. The smaller, firm, woody plants did well without shading, watering or other care except good cultivation. The larger plants died, where they were neither shaded nor watered. Those shaded during the day eventually became established for the most part altho a few died. Those watered but not shaded did a little better. Those watered freely and shaded during the day all lived and eventually became established. The smaller plants came into fruiting slightly ahead of the larger plants which were shaded and watered. They gave better results during the season.

Similar tests have been made during each subsequent season, with various vegetables. It has been found that early cabbage and cauliflower endure low temperatures with less injury if grown dry and less succulent. They may safely be planted to an open field much earlier. They wilt less, following transplanting.

In 1917, a frost followed the transplanting of firm and succulent tomato plants. The luxuriant plants were badly injured while the firm, smaller ones escaped serious injury.

All vegetables mentioned in the foregoing list transplant more readily and better endure cold or drouth if grown slowly as outlined above, with the exception of eggplants. Eggplants are easily "stunted" and develop better if luxuriant growth can be maintained thruout their life history. Cauliflower, if grown too slowly, or checked too suddenly, heads out prematurely and makes small heads. While it is not desirable to grow them too succulent care should be taken not to check their growth to a point where their product will be too small. Earliness to a marked degree may be secured, but at the expense of size of the product.

This matter is only briefly discussed here, giving the results of the preliminary work. Further work has now been planned as a definite Experiment Station project.

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THE PRESERVATION OF MILK FOR CHEMICAL ANALYSIS

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THE PRESERVATION OF MILK FOR CHEMICAL ANALYSIS

L. S. PALMER

With the technical assistance of L. H. Cooledge

INTRODUCTION

It is not always feasible for the chemist engaged in the analysis of milk to make all the determinations on the fresh sample. It is customary in such cases to add small quantities of various preservatives, such as formaldehyde, mercuric chloride etc., in order to prevent the fermentation and decomposition which milk undergoes on standing. Some study has been made of the proper quantity of these preservatives to add for ordinary preservation for short periods of time and the results have led to the adoption of what may be called standard amounts of these substances. For example, the official methods of the A.O.A.C.^{1*} recommend one part of formaldehyde to 2,500 parts of milk.

The problem of the preservation of milk for chemical analysis becomes more difficult, however, when it is necessary not only to prevent the common fermentations to which milk is subject but also to preserve the individual constituents of the milk unchanged for considerable periods of time. The need has long been felt for an efficient preservation of this kind. Unfortunately, our knowledge of the changes which the various milk constituents undergo under the influence of preservatives has been limited, so that the selection of any one or more preservatives which will give an efficient preservation of the several milk constituents has not been possible.

It was the purpose of the investigation reported in this bulletin to give the subject of milk preservation a more thorough study than it has hitherto been accorded. It was hoped that the results would lead to the selection of some method of milk preservation which would be more efficient from the standpoint of the individual constituents than the methods heretofore available.

*This and subsequent numerical references are to the Bibliography.

HISTORICAL²

The preservatives selected for comparison in this study were formaldehyde, mercuric chloride, potassium dichromate, copper sulfate, thymol, and toluene. Most of these preservatives have been the subject of more or less study at various times and a brief resume of what has been done along this line will, therefore, not be out of place.

Formaldehyde.—Price³ found that formaldehyde in the proportion 1:1560, after twenty-four hours incubation, had destroyed the common bacteria found in milk but that it required an incubation of seventy-two hours to destroy them in the presence of formaldehyde 1:1870. Rivas⁴ found that formaldehyde 1:1000 killed all the bacteria in certain milk samples. Seligman⁵ found that formaldehyde 1:5000 exerted a selective action on the bacteria of milk, preventing the development of lactic acid forming bacteria to a greater extent than other kinds. Schaps⁶ found that *Staphylococcus pyogenes* was more resistant than lactic acid bacteria to formaldehyde 1:5000 to 1:10000. Sommerfeld,⁷ studying the germicidal power of very dilute solutions of formaldehyde, i. e., 1:12,500 to 1:25,000, at various temperatures, found them to be effective at 10-15°C., only, or lower. At 37°C. there was no appreciable action of such dilute solutions of formaldehyde.

A number of investigators have made a study of the action of various enzymes of milk in the presence of formaldehyde, with the general result that their action has been bound to be greatly retarded and in some cases, perhaps, entirely inhibited. The only exception recorded is that of the oxidizing enzymes which Seligman⁵ found to be accelerated by the addition of formaldehyde 1:12,500.

The action of formaldehyde upon the natural proteoclastic enzyme of milk has been the subject of some study and is of special interest in connection with the preservation of milk for chemical analysis. Babcock, Russell, and Vivian,⁸ who named the proteoclastic enzyme of milk galactase, found that formaldehyde considerably weakened its activity. Freudenreich⁹ also found that one per cent formalin greatly retarded the proteolysis in skimmilk kept at 35°C. for six weeks, but did not prevent it entirely. Jensen,¹⁰ studying the activity of galactase in the presence of formalin at both room temperature and 35°C., found that there was no greater activity at the higher temperature in comparison with the lower, "probably because formalin, like other similar antiseptics, ex-

erts a much stronger influence at higher temperatures than at lower temperatures." Van Slyke¹¹ found that formaldehyde 1:2,500 greatly retarded the activity of the natural galactase of milk, especially in comparison with chloroform, when the milk was kept at 37°C., but did not prevent entirely the increase in soluble nitrogen. Tice and Sherman¹² made a study of the proteolytic changes in samples of milk kept at room temperature for eleven to forty-three months after the addition of formaldehyde in the proportions of 1:1000 to 1:1400, and found that the addition of the preservative had merely retarded the proteolysis. Price,⁸ studying the action of formaldehyde on the activity of digestive enzymes *in vitro*, found that formaldehyde 1:20,000 did not interfere with the action of galactase. He investigated two samples of milk containing formaldehyde 1:1000 and 1:1400, respectively, and found that when kept for two weeks at 40°C. there was no increase in the soluble nitrogen. He found also that adding formaldehyde in the proportion of 1:1500 to milk containing a concentrated extract of galactase in addition to its own natural enzyme content, retarded the activity of the galactase about 85 per cent but did not prevent it entirely.

There is some evidence to support the view that the retarding action of formaldehyde is due to some action which it exerts upon the proteins rather than to any actual inhibiting of the action of the enzymes. For example, a number of investigators¹³ have studied the retarding action of formaldehyde on the coagulation of milk by the rennet enzyme, and most of them agree with the view that this phenomenon is due to some action upon the casein of the milk. Cochran,¹⁴ especially, has shown that formaldehyde has a marked hardening action on casein, increasing with the length of time the formaldehyde is in contact and causing the casein to be much less soluble in concentrated sulphuric acid.

Formaldehyde forms methylene derivatives with free amino groups. Presumably this reaction takes place with all the free amino groups in a protein molecule when sufficient formaldehyde is present, but it is difficult to understand why this should interfere with the hydrolysis of the protein molecule which occurs at the peptid linkages. An explanation of the retarding action of formaldehyde on hydrolytic decompositions accelerated by enzymes must accordingly be sought in other directions, possibly in connection with an action upon some of the physico-chemical properties of either the proteins or the enzymes themselves, inasmuch as these properties of both proteins and enzymes are believed to be intimately connected with their reaction with one another.

Formaldehyde has been found to exert a detrimental influence upon certain of the properties of proteins. Thus Blum¹⁴ and Bach¹⁵ have found that both egg and serum albumin lose their coagulability by heat on treatment with formaldehyde. Lactalbumin appears to be similarly affected, Cavanaugh¹⁷ reporting that formaldehyde in certain concentrations considerably reduces the amount of lactalbumin which can be precipitated by heat.

With Cavanaugh's work as a basis, Patrick¹⁸ and a number of others investigated the effect of various preservatives, including formaldehyde, upon the recovery of albumin from milk by heat coagulation. The result of their study of formaldehyde was that concentrations of the preservative between one part in 310 of milk and one part in 630 caused an apparent increase in the casein at the expense of the albumin when the milk had been allowed to stand for about three weeks. This phenomenon was not noticeable in three out of four samples to which formaldehyde had been added in the proportion of one part to 1660 of milk. With still smaller concentrations of formaldehyde, i. e., 1:2000 to 1:2500, the samples showed evidence of proteolysis at the end of several weeks. The samples were all kept at room temperature in Patrick's investigation.

Mercuric chloride.—Very little work has been done on the effectiveness of this preservation, altho it is known to be a strong anti-septic.

Patrick¹⁸ in his study of milk preservatives, found that 2.5 to 5 grams of mercuric chloride per liter of milk acted very much like large amounts of formaldehyde, causing a marked increase in the casein nitrogen at the expense of the albumin. He secured no consistent results when a concentration of one gram per liter was used.

Tillmans, Splittgerber and Riffart¹⁹ comparing chloroform, thymol, mustard oil, phenol, creosote, sodium fluoride, potassium dichromate and mercuric chloride as milk preservatives found the latter only to be satisfactory. They recommend 0.03 to 0.04 per cent as the proper amount to use.

Gerber²⁰ studied the action of mercuric chloride toward both animal and vegetable rennets with the result that small amounts accelerated the rennet activity when added to the milk with the rennet. Large amounts, however, were found to retard the rennet activity.

Potassium dichromate.—This preservative is frequently used for milk, especially in European countries. For example, the French Government requires that it be used for milk samples which appear in legal cases.

Kühn²¹ found that potassium dichromate is a better preservative at low than at high temperatures.

Patrick¹⁸ has found, however, that this preservative does not prevent the decomposition of the casein and albumin of milk when used in as large amounts as 50 cc. of saturated solution per liter of milk.

Copper sulfate.—This preservative has never come into general use for milk altho it has been found to be strongly antiseptic toward certain mould spores. Gerber²⁰ has shown that it acts more unfavorably than mercuric chloride toward rennet.

The action of copper sulfate toward the milk proteins has never been studied.

Thymol.—This reagent has been used extensively as a preservative of feces and urine for chemical analysis, but very little mention is made in the literature of its use as a milk preservative. Richmond²² states that "it keeps the milk, but allows the cream to rise in so firm a layer that it is not readily redistributed."

Seligman⁵ found that thymol has no influence on the oxidizing enzymes of milk.

EXPERIMENTAL

In the various experiments reported in this bulletin attention was paid to the nitrogen distribution as represented by the casein, heat-coagulable protein, residual protein, and residual non-protein nitrogen. The total nitrogen was also determined in most cases. The percentage of fat and lactose was determined in a number of cases. In certain of the experiments tests for oxidase, peroxidase and catalase were performed, and bacterial counts made. The methods of analysis used were as follows:

METHODS OF ANALYSIS

Total nitrogen.—Five cc. of milk at 23°C. were pipetted into a Kjeldahl flask and digested with 25 cc. of concentrated H_2SO_4 , 0.2 grams of CuSO_4 , and 6.0 grams of K_2SO_4 , the digestion being continued for 45 minutes after the mixture became clear. In titrating back the unused acid with NH_4OH solution after distillation, Congo Red was used as indicator.

Casein.—Ten cc. of milk were pipetted into a clean beaker and warm water added until the temperature of the diluted milk was 44-46°C., the addition being adjusted so that the final volume was

about 140 cc. Approximately 14 cc. of 1.5 per cent acetic acid solution were then added from a burette with constant stirring. After settling, the precipitate was filtered off using a Munktell No. O. B. paper. The precipitate was washed with 0.15 per cent acetic acid, and the nitrogen determined upon the filter paper and precipitate as in the case of the total nitrogen.

Heat-coagulable protein.—The filtrate from the casein, together with the washings, which usually amounted to about 225 cc., was neutralized with dilute NaOH solution, using phenolphthalein as indicator, and 2 cc. of 1.5 per cent acetic acid solution added. The solution was then quickly raised to the boiling point and boiled for four minutes. The precipitate was filtered off and treated as in the case of the casein determination with the exception that it was washed with water only.

Residual protein.—Fifteen cc. of Almen's²³ tannic acid solution were added to the filtrate and washings from the heat coagulum. The precipitate, after standing a short time, was filtered off, washed with water, and the nitrogen determined as in the case of the heat-coagulable protein.

Residual non-protein nitrogen.—The filtrate and washings from the residual protein were rinsed into a Kjeldahl flask and the nitrogen content determined as in the case of the total nitrogen.

Fat.—Except where stated the fat was determined by the official Babcock asbestos method of the A.O.A.C., weighed portions of the whole milk being absorbed by asbestos in perforated copper cylinders, dried to constant weight in a steam oven, and extracted with ether for 24 hours, dried to constant weight again and the fat calculated from the loss in weight on extraction. In certain cases the fat was determined by the Babcock centrifugal method. Whenever this method was used it is so stated in connection with the data.

Lactose.—The lactose was determined by the official optical method of the A.O.A.C., using mercuric nitrate as the precipitant.

Bacterial counts.—Bacterial counts were made by the standard methods of the American Public Health Association for water analysis, using beef extract, however, instead of beef infusion. Two per cent of lactose was added for the lactose agar and lactose gelatin. The reaction of all media was brought to plus 1.0 per cent. The gelatin plates were incubated for three to five days at 20°C., and the agar plates for 24 to 36 hours at 38°C.

Oxidase and peroxidase tests.—All the enzyme tests were

taken from the work of Rogers, Berg and Davis²⁴. Oxidase and peroxidase were determined by placing 10 cc. of the milk in a test tube and allowing two to three drops of a freshly prepared, ten per cent, alcoholic solution of gum guaiac to run down the side of the tube so that the tincture remained on the upper surface of the milk. The tube was allowed to stand for five to ten minutes. The failure of a blue color to appear was taken to indicate the absence of oxidase. Two or three drops of dilute hydrogen peroxide solution were then added to the test tube. If peroxidase was present a blue color developed where the reagents came in contact. Usually a blue ring formed on or near the surface.

Catalase.—Fifty cc. of milk were introduced into a 100 cc. Erlenmeyer flask and 25 cc. of commercial hydrogen peroxide added. The flask was quickly closed with a stopper provided with a bent glass tube, the other end of which was then inserted into a fermentation tube (capacity 10 cc.) filled with water. The oxygen liberated by the catalase was caught in the tube and the amount liberated in fifteen minutes recorded. The reaction was practically complete in this time. The results are expressed as the percentage of the 10 cc. volume filled by the gas in the given time.

PRELIMINARY EXPERIMENTS

As a preliminary study a number of trials were made using formaldehyde, mercuric chloride, potassium dichromate, copper sulfate, thymol and toluene as preservatives, in which the preservatives were compared under like conditions. Several trials were made with each preservative, using various amounts. In these experiments attention was paid to the nitrogen distribution of the milk only. In reporting the results the experiment which showed the most efficient preservation in each case is given. These data are presented in Table 1. They represent the average of at least two, and in some cases several, concordant figures.

In presenting these data the heat-coagulable and residual protein nitrogen are shown separately and are also shown together in a separate column under the heading, total albumin and globulin. This procedure is followed thruout the entire bulletin.

At the time the data presented in this bulletin were taken the view was generally held that the relative proportion of non-heat-coagulable protein in milk, as determined by a reagent such as tannic acid, gave a measure of the decomposition of casein and albumin to

TABLE 1.—COMPARISON OF HCHO, $K_2Cr_2O_7$, $HgCl_2$, $CuSO_4$, THYMOL AND TOLUENE AS PRESERVATIVES OF MILK PROTEINS

Preservative	Concentration of preservative	Temperature of preservation	Time of analysis	Casein N.	Heat-Coag. N.	Residual protein N.	Total albumin and globulin N.	Residual non-prot. N.	Total N.
		°C	days	per cent	per cent	per cent	per cent	per cent	per cent
Fresh	0	—	1	0.357	0.061	0.041	0.102	0.028	0.496
HCHO —	1:2,500	8	29	.351	.034	.058	.092	.053	.496
Fresh	0	—	1	.379	.055	.038	.093	.028	.496
$K_2Cr_2O_7$ —	1:200	8	31	.356	.031	.074	.105	.028	.496
Fresh	0	—	1	.357	.061	.049	.110	.028	.496
$HgCl_2$ —	1:1,000	8	29	.359	.060	.033	.093	.050	.496
Fresh	0	—	1	.379	—	—	—	—	—
$CuSO_4$ —	1:350	8	35	.379	—	—	—	—	—
Fresh	0	—	1	.417	.056	.038	.094	.028	.533
Thymol —	1:5,000	2	17	.394	.074	.049	.123	.028	.533
Fresh	0	—	1	.407	.056	.038	.094	.028	.533
Toluene —	1:1,000	2	17	.392	.069	.050	.119	.028	.533

secondary proteins. Shortly after the completion of the experimental work certain experiments which the author carried out regarding the quantitative analysis of the albumin and globulin of milk threw considerable doubt upon the correctness of the interpretation of the data from this point of view.

In explanation of the delay in publishing these data it may be said that the author has now become convinced, as the result of much study and experimental work, that the distribution of albumin and globulin between coagulable and non-coagulable portions is purely an arbitrary matter, and that the circumstances which determine which fraction shall be the larger and which the smaller are largely fortuitous, as far as our present knowledge is concerned. The author no longer holds the view as tenable that tannic acid gives a measure of secondary proteins in milk after the albumin has been removed by heat coagulation. Fresh milk shows a high proportion of such secondary proteins even when heat-coagulation is carried out under the most carefully controlled conditions and by the most approved methods.

It does not seem to be generally recognized that there has never been any proof offered that fresh milk contains secondary proteins, except possibly in the merest traces. It is evident, therefore, that heat coagulation does not give an accurate measure of any protein constituent of milk, but is merely an arbitrary method subject

to wide variations, depending upon the kind of preservative used, the acidity and concentration of the solution, the length of time the solution is boiled, and other conditions. These facts are abundantly supported by much of the data given in this bulletin. According to the notion that heat-coagulation gives a measure of the albumin, there were very few of the experiments in which the "albumin" was not subject to extensive proteolysis on standing, in some cases for a very short time only, in contact with certain preservatives.

The variations between heat-coagulable and residual protein have therefore been disregarded in drawing conclusions in regard to the efficiency of the preservatives studied. The data are presented, however, in the exact form in which they were taken, but they are interpreted on the basis of variations in the casein, total albumin and globulin, and residual non-protein nitrogen.

It is recognized that this method is subject to the error that it gives no measure of any secondary proteins which have formed as the result of proteolysis, inasmuch as tannic acid causes a quantitative precipitation of most secondary proteins. However, since no practical method has, as yet, been devised for separating primary from secondary proteins quantitatively, it has been necessary to depend upon changes in the casein, and accompanying changes in the albumin and globulin and non-protein nitrogen for evidence of proteolytic changes in the milk. A marked increase in non-protein nitrogen at the expense of the other nitrogenous constituents would also justify the conclusion that proteolysis had taken place.

In the preliminary investigations, the principal results from which are shown in Table 1, formaldehyde appears to have been the most efficient preservative, altho there was some proteolysis of the albumin and globulin even in this case. Mercuric chloride apparently preserved the casein unchanged for 29 days when added in the proportion of one part to 1000 of milk. Potassium dichromate, thymol and toluene did not prove to be effective as preservatives of the protein constituents under the conditions studied. Proteolysis was so marked even under the best conditions that a future study of these preservatives was abandoned. The single brief test with copper sulfate, however, indicated that it deserved a much more thorough study.

One very important feature of the results of the preliminary studies was to point out the probable importance of factors other than the amount of preservative upon the efficient preservation of the milk. A second series of experiments was therefore undertaken

for the purpose of determining the importance of a number of secondary factors such as the temperature of preservation, the initial bacterial condition of the milk and the amount of air in contact with the sample. In nearly all of these studies the analyses were extended to include the percentage of fat and lactose in the milk.

INFLUENCE OF TEMPERATURE ON PRESERVATION

The object of this experiment was to study the influence of the temperature of preservation with four different preservatives. The temperatures studied were 2°C. and 14°C. The preservatives used were formaldehyde 1:2,500, mercuric chloride 1:1000, copper sulfate 1:350, and a mixed preservative consisting of formaldehyde 1:10,000, mercuric chloride 1:8,000 and thymol 1:4,000.

A large sample of milk was divided into 17 sub-samples each consisting of about 500 cc., which were then set aside at the desired temperature after the addition of the preservative. The containers for the samples were glass bottles. These were filled about nine-tenths full and well stoppered. One sub-sample was analyzed at once for fat, lactose, and the various protein constituents. Bacteriological counts were made at the same time. One set of the sub-samples was analyzed similarly at the end of three weeks and another at the end of fourteen weeks. The data from this experiment are given in Table 2.

The principal result of this experiment was the failure to confirm the results secured in the preliminary experiments showing the efficiency of formaldehyde as a preservative of the protein constituents of milk when used in the proportion of one part of 2,500 of milk. Appreciable proteolysis occurred in all the samples containing formaldehyde. The samples containing the mixed preservative were also very poorly preserved. Copper sulfate in the proportion of one part to 350 of milk apparently preserved the milk well at 2°C. for a period of three weeks, but considerable decomposition had taken place at the end of fourteen weeks.

In general the experiment shows clearly the importance of the temperature at which the samples are kept. In most of the samples there was a greater proteolysis in the samples kept at 14°C. in comparison with the corresponding samples kept at 2°C.

Another interesting result of this experiment was the apparently greater germicidal effect of mercuric chloride in comparison with the other preservatives.

TABLE 2.—INFLUENCE OF TEMPERATURE ON PRESERVATION

Preservative	Conc. of preservative	Temperature of preservation °C	Time of analysis days at once	Casein N.	Heat-coag. Prot. N.	Residual Prot. N.	Total Alb. and Glob. N.	Resid. Non-p. N.	Total N.	Fat per cent	Lactose per cent	No. of Bac. per cc.	No. of moulds per cc.
.....	.....	.....	.....	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent
HCHO	1:2,500	2	21	0.348	0.074	0.045	0.119	0.035	0.495	3.59	4.82	40,000	000
HCHO	1:2,500	2	98	.310	.086	.060	.146	.035	.495	3.57	4.80	25,400	70,000
HCHO	1:2,500	14	21	.309	.058	.088	.146	.039	.495	3.77	.....	850	8,920
HCHO	1:2,500	14	98	.321	.070	.066	.136	.037	.495	3.54	4.80	2,500	62,400
HgCl ₂	1:1,000	2	21	.301	.045	.085	.129	.056	.495	3.48	.....	600	3,700
HgCl ₂	1:1,000	2	21	.325	.111	.027	.138	.036	.495	3.61	4.81	160	000
HgCl ₂	1:1,000	2	98	.309	.096	.052	.148	.039	.495	3.63	.....	160	80
HgCl ₂	1:1,000	14	21	.298	.111	.042	.153	.036	.495	3.51	4.80	000	000
HgCl ₂	1:1,000	14	98	.263	.091	.088	.179	.047	.495	3.61	.....	400	12,000
CuSO ₄	1:350	2	21	.351	.083	.031	.114	.035	.495	3.44	4.80	20,700	400
CuSO ₄	1:350	2	98	.304	.081	.063	.144	.041	.495	3.63	.....	12,800	1,400
CuSO ₄	1:350	14	21	.318	.081	.060	.141	.035	.495	3.49	4.78	637,000	000
CuSO ₄	1:350	14	98	Spilled	.....	.....	.....	.....	.....	.....	.....	.....	.....
Complex	.....	2	21	.318	.081	.060	.141	.035	.495	3.59	4.77	123,000	20
Complex	.....	2	98	.279	.085	.093	.178	.042	.495	3.61	.....	300,000	20
Complex	.....	14	21	.282	.091	.085	.176	.041	.495	3.15	4.77	2,277,000	35
Complex	.....	14	98	.224	.067	.133	.200	.061	.495	3.51	.....	500	600

INFLUENCE OF DEVELOPMENT OF BACTERIA BEFORE ADDITION OF PRESERVATIVE

The object of this experiment was to study the influence of the development of a large number of bacteria before the addition of the preservative to the milk. This was accomplished by allowing the milk to stand for a period of time at 14°C. before adding the preservative. Two preservatives were used in this study, namely, formaldehyde in the proportion of one part to 2,500 of milk and the mixed preservative used in the previous experiment.

The technic of the experiment was as follows: A large sample of perfectly fresh milk was cooled at once to 14°C. and two sub-samples taken, one for immediate analysis and the other set aside at 2°C. after the addition of formaldehyde. The remainder of the milk was allowed to stand at 14°C. for 24 hours when three more sub-samples were taken, one for immediate analysis, and the other two set aside at 2°C. and 14°C., respectively, after the addition of formaldehyde. The remainder of the milk was then allowed to stand for 24 hours more when five sub-samples were taken, one for immediate analysis, two more treated as at the end of the first 24 hours and the remaining two in a similar way except that the mixed preservative was added to them. The remainder of the milk was then allowed to stand for 24 hours more, when five sub-samples were taken and treated as those withdrawn at the end of the second 24 hours.

All the sub-samples were analysed at the end of 26 days standing at the temperatures specified, with the exception of those indicated for immediate analysis.

Besides the analyses for fat, lactose and protein constituents, counts were made in all the samples for the number of bacteria and moulds. The results are given in Table 3.

The general result of this experiment was to show that an appreciably depreciatory influence is exerted upon the preservation of the milk constituents by allowing the milk to stand for more than 24 hours at 14°C. before adding the preservative. Even when the milk was subsequently kept at 2°C. marked proteolysis of the casein characterized the samples which stood longer than 24 hours before adding the preservative. When the samples were kept at 14°C. thruout the experimental period of 26 days proteolysis was marked in all cases, showing that the temperature at which they were preserved was a greater factor than the bacterial development which took place before the preservative was added. The lactose, also, was decomposed appreciably in these cases.

TABLE 3.—INFLUENCE OF DEVELOPMENT OF BACTERIA BEFORE PRESERVATION

Preservative	Temperature	Casein N.	Heat-coag. N.	Residual Prot. N.	Total Alk. and Glob. N.	Residual Non-prot. N.	Total N.	Fat	Lactose	Bacteria per cc.	Moulds per cc.	When analyzed	Time standing at 14°C. before pres. added.
None	14	0.367	0.078	0.041	0.119	0.041	0.528	3.68	5.15	210	0	at once	hours
None	14	.364	.085	.036	.121	.041	.525	3.56	5.13	10,000	0	after 24 hrs.	.....
None	14	.362	.086	.041	.127	.041	.527	3.65	5.11	550,000	0	" 48 "	.....
None	14	.353	.081	.049	.130	.041	.525	3.63	4.95	39,000,000	0	" 72 "	.....
HCHO 1:2500	2	.364	.071	.041	.112	.041	.528	3.54	.....	1,000	0	after 26 days	1
HCHO 1:2500	2	.364	.075	.042	.117	.041	.525	3.70	5.15	800,000	0	" 27 "	24
HCHO 1:2500	2	.353	.078	.056	.134	.041	.527	3.55	4.93	1,036,600	0	" 26 "	48
HCHO 1:2500	2	.338	.077	.071	.148	.041	.525	3.52	4.89	24,000	0	" 26 "	48
Complex	2	.361	.083	.053	.136	.034	.527	3.65	5.02	1,380,000	0	" 26 "	48
Complex	2	.336	.093	.063	.156	.039	.525	3.65	4.94	1,304,000	0	" 26 "	72
HCHO 1:2500	14	.277	.056	.069	.125	.125	.525	.....	4.46	41,730	1,120	" 27 "	72
HCHO 1:2500	14	.328	.078	.073	.151	.060	.527	3.35	4.90	50,400	0	" 26 "	48
HCHO 1:2500	14	.321	.081	.066	.147	.067	.575	3.75	4.34	908,000	4,000	" 26 "	48
Complex	14	.289	.049	.088	.137	.089	.527	3.18	4.51	78,230	0	" 26 "	72
Complex	14	.332	.089	.061	.150	.045	.525	3.90	.....	625,000	0	" 26 "	72

The gradual hydrolysis of the casein when fresh milk is allowed to stand at 14°C. is strikingly shown by the data for the first four samples in Table 3. There seems to have been some relation between the results of the analyses in these cases and the development of bacteria. The decomposition of the lactose apparently did not begin until after the milk had stood for 48 hours.

In general, it may be stated that the experiment does not reveal any consistent relation between the number of bacteria in the milk at the end of 26 days and the extent of the proteolysis which had taken place during this time.

INFLUENCE OF AIR ON PRESERVATION

The object of this experiment was to study the influence of air upon the preservation of the milk constituents, especially thru its relation to the growth of mould. The preservatives used were formaldehyde in the proportion of one part to 2,500 of milk and the mixed preservative used in the two preceding experiments. The plan of the experiment, together with the results secured are shown in Table 4.

The results of this experiment show that considerable air in contact with the milk has a marked influence upon the preservation of the milk constituents, apparently very appreciably increasing the proteolysis of all the protein constituents. The results show no connection, however, between this effect and the number of mould organisms which developed in the individual samples of milk. The figures show that the mould growth was relatively large in all the samples containing formaldehyde alone altho the amount of air in contact with the milk varied from none at all to a large quantity. Furthermore, at the end of 56 days the composition of the two samples preserved with the mixed preservative at 2°C. was almost identical with that of the corresponding samples preserved with formaldehyde alone altho the number of mould organisms in the samples containing the mixed preservatives was insignificant compared with the number in the samples containing formaldehyde alone.

The best preservation was obtained when the sample bottles were nine-tenths full. The cause of the detrimental effect of more or less air than this is not apparent.

This experiment gives an additional example of the fact that formaldehyde in the proportions of one part to 2,500 of milk is

TABLE 4.—INFLUENCE OF AIR ON PRESERVATION

Preserva- tive	Conc. of Pres.	Temp. of Pres.	Quantity of milk in bottle	Time of analysis	Casein N.	Heat- coag. Protein N.	Residual Prot. N.	Total Alb. and Glob. N.	Residual Non- Prot. N.	Total N.	Fat	Lactose	Bacteria per cc	Moulds per cc.
		°C	per cent	days	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent		
None	1:2,500	2	25	at once	0.348	0.074	0.047	0.121	0.035	0.494	3.59	4.82	40,000	0
HCHO	1:2,500	2	25	56	.303	.069	.081	.150	.053	.494	-----	4.74	288,000	821,600
HCHO	1:2,500	2	90	56	.316	.067	.068	.135	.038	.494	3.39	4.94	122,000	749,000
HCHO	1:2,500	14	50	56	.266	.054	.097	.151	.078	.494	3.48	4.86	77,080	533,000
HCHO	1:2,500	14	100	56	.293	.064	.091	.155	.049	.494	3.68	4.74	3,902,000	710,000
Complex	1:2,500	2	25	56	.305	.067	.081	.148	.038	.494	3.48	4.86	902,000	1,400
Complex	1:2,500	2	90	56	.318	.067	.078	.145	.038	.495	3.36	5.01	802,000	11,850
Complex	1:2,500	14	50	56	.233	.056	.127	.183	.081	.495	3.38	5.02	965,000	1,500
Complex	1:2,500	14	100	56	.274	.069	.100	.169	.049	.495	3.72	4.94	1,593,800	16,900

not a perfect preservative of the milk constituents even when the samples are kept at 2°C.

RELATIVE IMPORTANCE OF ENZYMES AND BACTERIA IN PRESERVATION OF MILK

The results secured in the experiments so far reported seem to justify the general conclusion that formaldehyde, under certain conditions, is probably as efficient a preservative of the various constituents of milk as any which is available at the present time. The best conditions which have been brought out so far are: (1) a concentration of formaldehyde of 0.04 per cent, or one part of formaldehyde to 2,500 of milk, (2) addition of the formaldehyde as soon as possible after drawing the milk, (3) leaving just sufficient air in contact with the sample to allow mixing, i. e., filling the bottle about nine-tenths full and (4) keeping the sample at 2°C.

The variable results obtained even under the foregoing conditions shows very clearly, however, that the chief factor causing the decomposition of milk in these cases was still not under perfect control. It seems very probable that this factor is the natural proteo-clastic enzyme, the galactase of the milk. A number of investigators, whose results have been reviewed in the preceding pages, have shown that formaldehyde merely retards the activity of this enzyme. Therefore it seemed advisable to give this question some study, particularly with reference to the relative importance of bacteria and enzymes in the preservation of the various milk constituents.

The night's milking from two individual cows was placed in separate covered cans and immediately brought to the cooler in which a temperature of 4-5°C. was maintained. The next morning five separate sub-samples were taken from each can and placed in 32-ounce glass-stoppered bottles. Each bottle was filled nine-tenths full. Each set of five samples was treated as follows: Sample 1 received no preservative and was analysed at once; Samples 2 and 3 received formaldehyde in the proportion of one part to 2,500 of milk, Sample 2 being analysed at the end of two weeks and Sample 3 at the end of six weeks; Samples 4 and 5 received 1.5 per cent chloroform, Sample 4 being analysed at the end of two weeks and Sample 5 at the end of six weeks. All the samples were kept at approximately 14°C. The fat in this and the subsequent experiments was determined by the Babcock centrifugal method.

It was expected that the samples containing chloroform would show considerably more proteolysis than the samples containing for-

maldehyde if the inconsistencies of the results previously obtained were due to the activity of galactase. This expectation was based on the results secured by Harding and Van Slyke²⁵ who found that 1.5 per cent chloroform acted as a strong germicide but did not retard the activity of the proteoclastic enzyme of milk.

It seemed advisable as a preliminary test to determine whether 1.5 per cent chloroform in the milk would have any effect upon the proportion of the protein constituents of milk as determined by the methods of analysis which had been adopted for these studies. For this purpose a sample of milk was divided into two parts; formaldehyde was added to one part in the proportion of one part to 2,500 of milk, and 1.5 per cent chloroform was added to the other part. The two samples were then analyzed at once for the various protein constituents. The results of the test are given in Table 5. The data show that no effect is produced upon the usual distribution of nitrogen in milk due to the presence of this amount of chloroform.

TABLE 5.—COMPARISON PROTEIN DISTRIBUTION IN MILK PRESENCE OF HCHO 1:2,500 AND CHCl₃ 1.5 PER CENT

Constituent	HCHO 1:2,500	CHCl ₃ 1.5 per cent.
Casein N. per cent	0.406	0.400
Heat-coagulable protein N. per cent	.060	.065
Residual protein N. per cent	.050	.056
Total albumin and globulin N. per cent	.118	.121
Residual non-protein N. per cent	.030	.030
Total N. per cent	.553	.553

In the experiment proper the results of the analyses of the samples of milk from the two cows were characterized by such a uniformity that it seemed permissible to present the data in the form of an average. The data from this experiment are shown in Table 6.

A study of the data in this table leads to the conclusion that the most important factor to be controlled in bringing about a satisfactory preservation of the protein constituents of milk is the action of the proteoclastic enzyme galactase. Under the conditions of this experiment formaldehyde in the proportion of 1 to 2,500 of milk greatly retarded this action but did not prevent it entirely. Satisfactory preservation was secured for two weeks with formaldehyde but the samples did not show an analysis identical with the fresh milk after standing for a period of six weeks.

TABLE 6.—COMPARATIVE PRESERVATION OF MILK IN PRESENCE OF HCHO, 1:2,500 AND CHCl₃, 1.5% RESPECTIVELY

Constituent	Analysis of fresh milk	Milk preserved with 1.5% CHCl ₃		Milk preserved with HCHO, 1:2,500	
		After 2 weeks	After 6 weeks	After 2 weeks	After 6 weeks
Casein N.—per cent	0.368	0.318	0.260	0.364	0.354
Heat-coag. protein N.—per cent.....	.046	.067	.073	.050	.039
Residual protein N.—per cent.....	.061	.073	.108	.055	.072
Total albumin and globulin N.—per cent .....	.107	.140	.181	.105	.102
Residual non-protein N.—per cent.....	.031	.040	.043	.034	.038
Total N.—per cent .....	.505	.505	.505	.505	.505
Fat—per cent	3.65	3.65	3.65	3.49	3.49
Lactose—per cent	4.94	4.87	4.84	4.87	4.78
Peroxidase—per cent.....	+++	++++	++++	++++	+
Catalase—per cent	47	68	58	10	15
Acid bacteria per cc.	85,000	0	0	35,000	15
Peptonizing bacterial per cc.	52,000	0	0	0	15
Alkaline and inert bacteria per cc.....	9,885,000	0	0	40,000	70
Total bacteria per cc.	10,022,000	575	10	75,000	100
Moulds per cc.	1,075,000	0	0	900	7,350

INFLUENCE OF INCUBATION WITH PRESERVATIVE ON DESTRUCTION OF BACTERIA AND ENZYMES

The experiments so far conducted show very clearly that the two most important conditions to be secured for the efficient preservation of the various constituents of milk are that the bacterial of the milk be destroyed and especially that the action of the proteoclastic enzymes be inhibited.

As has already been stated, the best preservative found in the studies made thus far is formaldehyde in the proportion of one part to 2,500 of milk when used under certain conditions, which have been mentioned. One of the most important of these conditions, namely, keeping the milk at a low temperature, is frequently not feasible under practical laboratory routine. The temperature most feasible for most laboratories to maintain is that of the well cooled ice box, which is 8°-10°C. All the remaining experiments were accordingly planned with this temperature as a basis. The experiments so far reported show, however, that efficient preservation can not be expected at a temperature of 10°C. without introducing some controlling factors other than those already mentioned.

Formaldehyde is recognized as a strong germicidal agent and the data presented in Table 7 show that this effect is considerably

TABLE 7.—INCREASED GERMICIDAL EFFECT OF HCHO AT INCUBATION TEMPERATURE

Character of test	Bacteria per cc.		
	At start	After 6 hours	After 48 hours
HCHO, 1:2,500, placed in cooler at 10°C.	10,000	1,700	100
HCHO, 1:2,500, placed in incubator at 37°C	10,000	20	5

augmented by allowing the formaldehyde to act at the temperature most favorable for the growth of most bacteria, namely, 37°C. This result suggested the possibility that a similar procedure might also decrease the activity of the proteoclastic enzymes. It has already been pointed out that Jensen¹⁰ found the proteoclastic enzymes of milk to be no more active at 35°C. than at room temperature in the presence of 1.0 per cent formalin (formaldehyde 1:250). He attributed this result to the fact that the greater activity of the enzymes at 35°C. is counterbalanced by the greater antiseptic power of the formaldehyde at the higher temperature. In Jensen's experiments the samples were kept continuously at the temperatures studied. It seemed therefore worth while to investigate whether a short incubation in the presence of formaldehyde would result in a more favorable destruction of the enzymes of the milk, particularly those which accelerate the hydrolysis of the proteins.

EXPERIMENT 1.—A sample of fresh milk was divided into three portions, and each portion placed in a 32-ounce glass-stoppered bottle filled nine-tenths full. One of the samples was analyzed immediately. Formaldehyde 1:2,500 was added to each of the remaining samples and one was placed in the cooler at 8°-10°C. and the other in the incubator at 37°C. for 48 hours and then in the cooler. Both of these samples were analyzed at the end of six weeks. The results of the experiment are given in Table 8.

TABLE 8.—INFLUENCE OF INCUBATION WITH FORMALDEHYDE ON SUBSEQUENT PROTEOLYSIS AND OTHER CHANGES IN MILK

Constituent	Analysis of fresh milk	HCHO1:2,500. After 6 weeks at 10°C.	HCHO1:2,500. 48 hours at 37°C. After 6 weeks at 10°C.
Casein N.—per cent	0.370	0.357	0.361
Heat-coag. protein N.—per cent .....	.050	.036	.038
Residual protein N.—per cent .....	.067	.075	.072
Total albumin and globulin N.—per cent .....	.117	.111	.110
Residual non-protein N.—per cent .....	.030	.050	.034
Total nitrogen—per cent .....	.517	.517	.517
Fat—per cent	3.22	3.22	3.22
Lactose—per cent	4.98	4.76	4.96
Oxidase	None	None	None
Peroxidase	++	+	None
Catalase—per cent	57	22	25
Acid bacteria per cc.	20,000	20	0
Peptonizing bacteria per cc.	30,000	20	0
Alkaline and inert bacteria per cc.....	850,000	60	0
Total bacteria per cc.	900,000	100	0
Moulds per cc.	450,000	13,000	0

The data show that the effect of incubation was to increase greatly the germicidal power of the formaldehyde. There was, however, very little increased inhibition of the activity of the proteoclastic enzymes as the result of the incubation.

Altho this experiment failed to give satisfactory evidence that incubation at 37°C. gives an effective enzyme antisepsis the question seemed worthy of more extended study, particularly with reference to the effect of greater concentrations of formaldehyde than the one used in this experiment.

EXPERIMENT 2.—A portion of a sample of milk was set aside for immediate analysis for percentage of total soluble protein nitrogen and the remainder of the milk sub-divided into a number of samples to which various preservatives were added. These sub-samples were kept at 37°C. for two weeks, when the percentage of soluble nitrogen was again determined. The results of the experiment are shown in Table 9.

The data from this experiment show very clearly the relative antiseptic power of the various preservatives toward proteolysis. The relative efficiency of the different concentrations of formaldehyde is also strikingly shown.

The marked proteolysis of the samples containing toluene and benzene in comparison with the samples containing the same concen-

tration of these preservatives plus formaldehyde demonstrates clearly that the proteolysis with which we are dealing in the preservation of milk is of enzyme origin. In addition these results indicate that formaldehyde is probably the most powerful antiseptic toward this enzyme which is available at the present time. According to E. Fisher²⁶ toluene has scarcely any destructive action toward enzymes, while it prevents the growth of protoplasmic structures.

TABLE 9.—INFLUENCE OF INCUBATION WITH VARIOUS PRESERVATIONS UPON PROTEOLYSIS

Preservative	Soluble protein N. at start.	Soluble protein N. after 2 weeks
HCHO 1:2,500	0.151	Spoiled
HCHO 1:1,250	0.151	0.149
HCHO 1:625	0.151	0.144
HgCl ₂ 1:1,000	0.151	0.204
Benzene 1:20	0.151	0.270
Toluene 1:20	0.151	0.274
HCHO 1:2,500, Benzene. 1:20	0.151	0.141
HCHO 1:2,500, Toluene. 1:20	0.151	0.141

Note: The results of the analyses of the samples containing benzol and toluene were corrected for volume of these reagents added.

Of the several concentrations of formaldehyde used in this experiment one part to 1250 parts of milk is shown to be the best. The curdling of the sample containing one part of formaldehyde to 2,500 parts of milk shows that this concentration was not sufficiently great to prevent the development of lactic acid bacteria at the incubation temperature, while the concentration of formaldehyde of 1:625 evidently caused the precipitation of some of the albumin as casein, as was shown by Patrick¹⁸ and his co-workers to take place with this concentration of formaldehyde.

EXPERIMENT 3.—The object of this experiment was to show the effect of a 48-hour incubation with formaldehyde 1:1250 upon the preservation of the various milk constituents, the milk to be kept subsequently at about 10°C. For comparative purposes other samples of the same milk were (1) kept at the incubation temperature, (2) kept at about 10°C. without previous incubation, (3) kept at room temperature without previous incubation, and (4) incubated for 48 hours and kept at room temperature.

A large sample of milk was subdivided as in the other experiments of this character, and one portion analyzed immediately.

The other sub-samples, to which preservative was added, were placed in 32-ounce glass-stoppered bottles, filled nine-tenths full. The duration of the preservation period was thirty days. The data from this experiment are given in Table 10.

TABLE 10.—INFLUENCE OF INCUBATION TEMPERATURE WITH HCHO 1:1,250 ON PRESERVATION OF MILK CONSTITUENTS

Constituent	Analysis of fresh milk	Analyses after six weeks				
		Kept at 3°C.	37°C. for 48 hours then 10°C.	Kept at 10°C.	Kept at 20°C.	37°C. for 48 hours then at 20°C.
Casein N.—per cent	0.446	0.446	0.457	0.444	0.431	0.450
Heat-coag. protein N.—per cent .....	.053	.024	.034	.036	.030	.028
Residual protein N.—per cent .....	.049	.072	.056	.064	.069	.060
Total albumin and globulin N.—per cent .....	.112	.096	.090	.100	.099	.088
Residual non-protein N.—per cent .....	.028	.033	.028	.030	.035	.027
Total N.—per cent .....	.577	.577	.577	.577	.577	.577
Fat—per cent	4.10	3.90	3.90	3.90	3.90	4.00
Lactose—per cent	5.02	5.02	5.02	5.02	5.02	5.00
Oxidase	None	None	None	None	None	None
Peroxidase	+++	"	"	+++	+	"
Catalase—per cent	30	20	20	20	20	20
Bacteria per cc	3,000	50	120	200	500	100

The results obtained in this experiment were somewhat surprising in that the sample preserved at 10°C. without previous incubation proved to be the best preserved at the end of thirty days. The loss of casein and soluble proteins in this sample was, in fact, negligible. The data indicate that for efficient preservation of the protein constituents of milk using formaldehyde as preservative, an amount considerably in excess of that usually recommended must be used.

The experiment shows clearly the effect of formaldehyde upon the relative distribution of heat-coagulable and residual protein in the milk. The data therefore serve to emphasize the fallacy of drawing conclusions regarding the albumin content of milk based upon its estimation by coagulation with heat.

THE MINIMUM QUANTITY OF FORMALDEHYDE FOR PRESERVATION

In order to determine more closely the minimum quantity of formaldehyde which will serve as an efficient preservative of the milk constituents, especially the milk proteins, a further experiment was planned.

A large sample of fresh milk was divided into 15 sub-samples which were placed in 32-ounce glass-stoppered bottles filled nine-tenths full. These sub-samples were then divided into five groups of three each, to which were added formaldehyde in the proportions of 1:1,400, 1:1,600, 1:1,800, 1:2,000 and 1:2,200, respectively. One of the three samples of each group was analysed immediately. Another sample of each group was placed in the refrigerator at about 10°C. The third sample of each group was placed in the incubator at 37°C. The samples in the refrigerator were analyzed at the end of five days.

TABLE 11.—INFLUENCE OF DIFFERENT CONCENTRATIONS OF HCHO ON PRESERVATION OF MILK

Constituent	When analyzed	Proportion of HCHO in sample				
		1:1,400	1:1,600	1:1,800	1:2,000	1:2,200
Casein N. _____	at once	0.379	0.379	0.379	0.379	0.379
Casein N. _____	after 5 days at 37°C.	.392	.386	.377	.373	.370
Casein N. _____	after 5 days at 10°C.	.378	.373	.365	.372	.359
Total albumin and globulin N.	at once	.105	.105	.105	.105	.105
Total albumin and globulin N.	after 5 days at 37°C.	.097	.102	.108	.110	.113
Total albumin and globulin N.	after 5 days at 10°C	.108	.110	.119	.113	.121
Residual non-protein N. _____	at once	.033	.033	.033	.033	.033
Residual non-protein N. _____	after 5 days at 37°C	.036	.034	.036	.038	.039
Residual non-protein N. _____	after 5 days at 10°C	.031	.034	.034	.033	.033
Total N. _____	at once	.517	.517	.517	.517	.517
Total N. _____	after 5 days at 37°C	.524	.522	.518	.518	.522
Total N. _____	after 5 days at 10°C	.518	.517	.517	.517	.511

The data from this experiment are presented in Table 11. They indicate clearly that the minimum quantity of formaldehyde necessary to preserve efficiently the protein constituents of milk, using

ordinary cooling facilities, is approximately one part to 1,700 of milk. Amounts in excess of this up to one part to 1,400 of milk appear to be permissible also. When incubation is used to facilitate the destruction of bacteria and enzymes it is apparently impracticable to use formaldehyde in excess of one part to 1,800 of milk without affecting the determination of casein and soluble proteins.

THE PRESERVATION OF A COMPOSITE SAMPLE

Studies involving the chemical analysis of milk are not always made on samples representing merely one milking or one day's yield of milk but are frequently made on samples representing several days' yield and more often on the milk of an entire week. In such cases a composite sample is made of the days to be represented and at the end of the sample period a sub-sample is taken from the composite which represents the average composition of the milk during that period. A study of the preservation of milk for chemical analysis would therefore be incomplete without extending the results to a study of their applicability to the preservation of a composite sample.

It was planned to make all the conditions of this experiment as practical as possible. None of the samples were subjected to incubation, as previous experience had not given results of sufficient value to warrant this step. Instead, the samples were kept in the refrigerator at about 10°C. The preservative used was formaldehyde in the proportion of one part to 1,500 of milk, added, as in all other experiments, in the form of formalin.

The night and morning milkings of a selected cow were brought to the refrigerator immediately after milking. In the morning the two milkings were combined and treated as follows:

1. The milk was mixed thoroly by pouring from can to can.
2. A 32-ounce glass-stoppered bottle was filled nine-tenths full of the thoroly mixed milk. The bottle was labeled Sample I, and was set aside for immediate analysis.
3. The remaining milk was carefully measured and formaldehyde added in the proportion of one part to 1,500 of milk.
4. A 32-ounce glass-stoppered bottle was filled nine-tenths full of the formaldehyde treated milk. The bottle was labeled Sample 1, and placed in the refrigerator.
5. Ten per cent of the measured, formaldehyde-treated milk of Step 3 was placed in a five-liter bottle for the composite sample. This bottle was kept at about 10°C.

At the end of three days another night and morning milking from the same cow was treated according to the steps given above. The sample of fresh milk for immediate analysis was labeled Sample II. The formaldehyde-treated milk in Step 4 was labeled Sample 2. In Step 5 the ten per cent of the measured milk which was withdrawn was added to the five-liter bottle containing the similar sample prepared three days previously.

At the end of three more days the same procedure was carried out. The sample of fresh milk was labeled Sample III. The sample of formaldehyde-treated milk taken in Step 4 was labeled Sample 3. Ten per cent of the measured milk was added to the five-liter bottle set aside for that purpose.

After the third portion of the composite was added to the five-liter bottle the contents were thoroly mixed and two sub-samples taken in 32-ounce bottles, as in the other samples, and labeled Sample IV and Sample VI, respectively. Sample IV was set aside for immediate analysis, and Sample VI analyzed at the end of three weeks in the refrigerator. At the time of analysis of Sample VI the sub-samples labeled 1, 2 and 3 were united and a sub-sample taken from the mixture. This was labeled Sample V and was analysed with Sample VI.

The data from this experiment are shown in Table 12. They show that the method used in this experiment for making a com-

TABLE 12.—PRESERVATION OF A COMPOSITE SAMPLE FOR 3 WEEKS WITH HCHO 1:1,500

Sample:	Casein N.	Albumin and globulin N.	Residual non-protein N.	Total N.	Fat	Lactose
	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>
I* ———	0.439	0.102	0.028	0.572	5.05	5.47
II** ———	.445	.111	.031	.586	5.12	5.47
III† ———	.417	.114	.028	.560	4.90	5.47
IV†† ———	.434	.113	.028	.569	5.05	5.47
V‡ ———	.431	.110	.028	.566	4.95	5.40
VI‡‡ ———	.431	.107	.027	.566	4.95	5.40

*First day.

**Third day.

†Sixth day.

††Composite of I, II, & III analyzed at once.

‡Composite of duplicates of I, II, & III made and analyzed at end of 3 weeks.

‡‡Duplicate of Sample IV analyzed after 3 weeks.

posite sample and preserving it for future study gave a satisfactory preservation of the milk constituents. The two composites, namely, Samples V and VI, were practically identical with one another and also with Sample IV, in composition.

SUMMARY AND CONCLUSIONS

In this bulletin a detailed study of the preservation of milk for chemical analysis is reported, particularly with reference to the preservation of the protein constituents.

The experiments which were carried out were designed to show the influence of the following factors upon the preservation of milk: (1) The kind of preservative; (2) the temperature of preservation; (3) the development of bacteria before adding the preservative; (4) the amount of air in contact with the milk; (5) the relative importance of bacteria and enzymes in causing decomposition; and (6) the minimum quantity of the best preservative to use.

The preservatives selected for comparison were formaldehyde, mercuric chloride, potassium dichromate, copper sulfate, thymol, and toluene. Formaldehyde is shown to be the most efficient of these reagents in the comparisons which were made.

It is shown that milk is preserved best at a temperature near the freezing point but an effort was made to establish the proper conditions for an equally efficient preservation at a temperature of approximately 10°C., as being more practicable for the average laboratory to maintain.

It was found inadvisable to allow milk to stand for more than twenty-four hours at 14-15°C. before adding the preservative. The data in regard to this factor suggest that milk which is to be preserved for future chemical analysis should be cooled at once to the temperature at which it is to be preserved and the preservative added immediately.

The amount of air in contact with the sample of milk is shown to be an important factor in efficient preservation, more than just enough air to permit subsequent mixing of the sample being detrimental to the preservation of the milk. Filling the sample bottles nine-tenths full was found to be a safe practice.

The destruction of enzymes, particularly the natural proteolytic enzymes of the milk, is shown to be the most important condition to be secured for the efficient preservation of milk, since most preservatives are much stronger germicides than inhibitors of enzyme action.

A study of the effect of holding the milk for a short time at 37°C. in the presence of formaldehyde, on the destruction of the natural proteoclastic enzyme of milk did not result in sufficiently greater efficiency to warrant the recommendation of the procedure in actual practice.

Proportions of formaldehyde not less than one part to 1,700 of milk and not greater than one part to 1,250 are shown to be the most efficient quantities of this preservative to add to milk to bring about a satisfactory preservation of the various constituents for three to four weeks.

It is shown, however, that these quantities of formaldehyde do not permit the use of heat-coagulation for determining the "albumin" of milk. Some discussion is given to the use of this method of analysis under any conditions, and its limitations pointed out.

A study of the preservation of a composite sample using formaldehyde 1:1,500 as preservative led to satisfactory results.

A study of the entire data in this bulletin suggest that the following procedure can be safely recommended as a satisfactory one for the preservation of all the constituents of milk for a period of several weeks.

METHOD RECOMMENDED FOR PRESERVATION OF MILK

Mix the sample thoroly as soon as drawn; measure carefully one liter and add between 1.5 and 2.0 cc. of formalin (containing approximately 40 per cent formaldehyde); place a suitable portion in a bottle, preferably a glass-stoppered one, filling the bottle about nine-tenths full; cool at once to 8-10°C. or lower and maintain at that temperature until ready for analysis.

ACKNOWLEDGMENT

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A STUDY OF THE BIRTH WEIGHT OF CALVES

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¹In service of U. S. Department of Agriculture.

A Study of the Birth Weight Of Calves

C. H. ECKLES*

The marked variations in the size of calves at birth has attracted the attention of all close observing cattle breeders. Such observations naturally give rise to questions concerning the extent and cause of such variations, as well as their possible significance from the standpoint of the future welfare of the animal.

A limited amount of data on this subject have been reported by Beach,¹ Henry and Morrison,² and Eckles.³ The new data to be presented were taken under the supervision of the author, and represent those accumulated during a period of twelve years from the dairy herd owned by the University of Missouri.

The animals included were all purebred and registered. The Holsteins and Ayrshires represented lines of breeding common in prominent herds and were considered to be entirely typical of the breeds. The Jerseys were of the lines of breeding generally known as the American type, altho some, the younger animals, represent one-fourth or one-half of the blood of those lines of breeding known as the Island type. The dairy Shorthorns were registered Shorthorns and represent the extreme dairy type of this breed. The lines of breeding represented are, however, among those used in the very best known herds of this breed. Unfortunately, the Guernsey breed is not represented in this herd and consequently no data are available.

For the last twelve years each calf dropped in the University of Missouri herd has been weighed soon after birth, usually within five hours. The dams have been weighed under conditions as nearly uniform as practicable, for three days in succession following calving, and the average of the three weights of the dam following calving has been used.

*Resigned, March, 1919.

¹Beach, C. L. The Birth Weight of Calves. Storrs Agr. Exp. Sta. 19th Annual Report, p. 147. 1907.

²Henry, W. A. and Morrison, J. B. Feeds and Feeding. Ed. 15, p. 424. 1915.

³Eckles, C. H. Dairy Cattle and Milk Production, p. 174. 1912.

One of the difficulties encountered in compiling data of this kind is to determine where the line shall be drawn between normal and abnormal gestation periods. As a result of accident or contagion the foetus may be expelled at any point during gestation. The question as to what is normal arises especially with gestation periods decidedly shorter than usual but which result in a living calf that may be raised to maturity.

The Earl of Spencer,⁴ in his well-known report concerning the gestation period of cattle, states that the shortest gestation period from which he was able to raise the calf born was 242 days, but he states also that any gestation less than 260 days must be considered premature. Wing,⁵ in his study of 192 gestation periods, reports that the shortest was 264 days. In the compilation of the data here given, gestation periods less than 260 days have been omitted. A few calves born following a gestation period shorter than this have been successfully raised but such cases are clearly abnormal and it is considered fair to draw the line at this point.

RELATION OF BREED AND SEX TO BIRTH WEIGHT

The most important factor influencing the weight of the calf at birth is that of breed. Table 1 gives the data on this point. It shows that the Jersey calf, averaging 55 pounds, is the smallest

TABLE 1.—BIRTH WEIGHT OF CALVES, UNIVERSITY OF MISSOURI HERD

Breed	Average of both sexes		Males		Females		Weight of calf in proportion to dam
	Number	Average weight	Number	Average weight	Number	Average weight	
		Pounds		Pounds		Pounds	Per cent
Jersey	196	55	102	58	94	53	6.5
Holstein	154	90	69	93	85	88	8.0
Ayrshire	53	69	27	73	26	65	6.9
Dairy Shorthorn	30.	73	11	74	19	73	6.0

for the breeds represented, and the Holstein with an average of 90 pounds is the largest. The figures expressing the weight of the calf in percentage of the weight of the dam shows that the Jersey not only has the smallest calf in weight but that the calf is the smallest in proportion to the dam. The Holstein calf, in addition

⁴Spencer, the Earl of. Gestation Period in Cattle. In Journal of Royal Agricultural Society of England, v. I, pp. 165-169. 1840.

⁵Wing, H. H. The Period of Gestation in Cows. Cornell University Agr. Exp. Sta. Bul., 162, pp. 323-334. 1899.

to being the largest of all in weight, is also the largest in proportion to the weight of the dam. These data also bear out the common opinion that male calves average larger at birth than do females. The Jerseys and Holsteins show a difference of five pounds between the sexes, the Shorthorns one pound, and the Ayrshires, eight pounds. Figure 1 shows the frequency distribution of the weights of the 196 calves of the Jersey breed including both sexes. It will be noted that over 60 per cent of all birth weights fall within 48 to 62 pounds, which is within a limit of seven pounds on either side of the average.

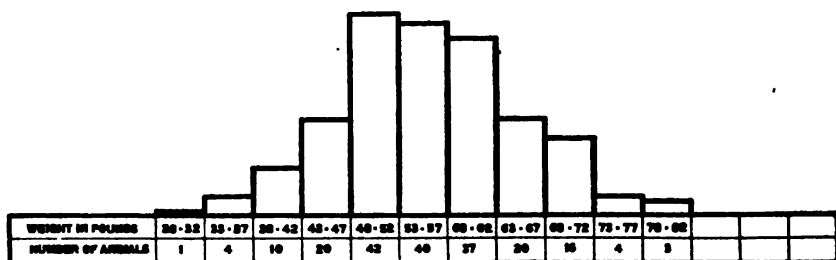


Fig. 1.—Frequency distribution of the weights of Jersey calves at birth, including both sexes. The average weight was 55 pounds.

Table 2 is a combination of all data available for dairy breeds including those presented in this paper and those summarized by Henry and Morrison.

TABLE 2.—BIRTH WEIGHTS OF CALVES OF THE DAIRY BREEDS
All available data

Breeds	Number of calves	Average weight both sexes	Average weight of dams
		<i>Pounds</i>	<i>Pounds</i>
Jersey	253	55	867
Holstein	229	89	1137
Guernsey	57	71	996
Ayrshire	80	72	983
Brown Swiss	5	100	1123
Dairy Shorthorn	30	73	1216

RELATION OF AGE OF DAM TO BIRTH WEIGHT

Table 3 gives the data for the Jersey and Holstein breeds arranged to show the average birth weight of calves in relation to the age of the dam. The dams averaged close to twenty-nine months

of age at the time of birth of the first calf. The intervals between the birth of successive calves in the herd from which the data are taken average about thirteen months. For this reason it cannot be assumed, as might be possible in some commercial herds, that the

TABLE 3.—INFLUENCE OF AGE OF DAM UPON WEIGHT OF CALF AT BIRTH

Number of Calf	Jerseys		Holsteins	
	Number of calves included	Average weight	Number of calves included	Average weight
		<i>Pounds</i>		<i>Pounds</i>
First	44	51	45	85
Second	35	55	31	88
Third	35	58	26	95
Fourth	18	62	19	93
Fifth	13	58	10	101
Sixth	16	52	5	90
Seventh	14	56	7	103
Eighth	8	56	5	98
Ninth	4	53	5	85
Tenth	3	64	2	89
Eleventh	3	51	—	—
Twelfth	2	50	—	—

first calf represents an age of two years for the dam, and each successive calf an interval of a year. The data show that the first calf is noticeably smaller than the second and third, and smaller than the average for the breed. On the average, the maximum weight for calves at birth will be found among those representing from the third to the sixth calf of the dam. The number of calves from the cows of advanced age is too limited for a safe conclusion to be drawn concerning the relation of extreme age to size of the calf. There are, however, indications of a tendency for the calves to be somewhat smaller after the seventh or eighth is reached, which represents an age of ten to twelve years for the dams. Between the ages of five and ten years the cow is, ordinarily, at her best for milk and the calves are at the maximum in size. Experience indicates that the same holds true regarding the vigor of the calves from cows between these ages.

LENGTH OF GESTATION PERIOD

Another possible factor influencing the weight of calf at birth is the length of the gestation period. The expulsion of the foetus before the normal time would be expected to result in an undersized calf. As previously mentioned, it is a difficult matter to decide how

short the gestation may be and still be classed as normal. The data given do not include any periods of less than 260 days. Table 4 gives the average length of the gestation period for Jersey calves grouped according to weight at birth. It appears from these data

TABLE 4.—RELATION OF LENGTH OF GESTATION PERIOD OF JERSEY COWS TO WEIGHT OF CALF AT BIRTH

Number of animals	Weight limits	Gestation period
	<i>Pounds</i>	<i>Days</i>
4	33 to 37	274
10	38 to 42	277
20	43 to 47	279
42	48 to 52	281
41	53 to 57	281
34	58 to 62	282
19	63 to 67	284
13	68 to 72	284
3	73 to 77	281
3	78 to 82	285

that the length of the gestation period is correlated to some extent with the size of the calf at birth, since the length of the gestation period is clearly longer for larger calves. This factor, however, is one of limited importance.

RELATION OF THE SIZE OF THE DAM

Table 3 shows that on the average the first calf is lighter in weight than those born from mature animals. It is not clear from these data whether the cause of the lower weight for first calves is the smaller size of the dams or the immaturity in age. This point was studied further by compiling the weights of the dams of the Holstein breed following the first parturition, into groups based upon their weights. These data are given in Table 5. These figures

TABLE 5.—INFLUENCE OF WEIGHT OF DAM UPON WEIGHT OF CALF AT BIRTH

	Average weight of dam	Average weight of calf	Weight in proportion to dam
	<i>Pounds</i>	<i>Pounds</i>	<i>Per cent</i>
800 to 800 pounds	834	79	9.4
900 to 1000 pounds	948	87	9.4
1000 to 1100 pounds	1090	92	8.4

show a consistent relation between the weight of the dam and of the calf and suggest that the smaller weights of the first calves of heifers is probably due to the smaller size of the dam rather than to her immaturity. Data are not available for a sufficient number of undersized mature cows to carry the comparison further. That the breed factor is also present is shown by the fact that the calves from the young cows are somewhat heavier in proportion to their dams than those from the mature cows.

INFLUENCE OF THE SIRE ON WEIGHT OF CALVES

The possible relation of the sire to the size of the off-spring is of interest in considering the factors that may influence the size of the calves at birth. Mumford⁷ concluded from his observations with sheep that the size of the sire did not exert any influence upon the birth weight of the lambs. The data available concerning the birth weight of the calves, altho more extensive than yet reported, involve the offspring from many sires and a safe basis is not furnished for generalization on this point. However, a study of the data from this viewpoint does not indicate any variation that can safely be attributed to this cause.

The data include a few cases of cross-breeding and these show unmistakable evidence that under these conditions the sire does influence the size of the offspring. Calves dropped by three purebred Jersey cows and sired by a purebred Holstein bull averaged 73 pounds in weight, while other calves from the same cows sired by a Jersey bull averaged 56 pounds in weight. Three calves sired by a Holstein bull from Ayrshire cows averaged 80 pounds, compared with an average of 66 pounds for three calves from the same cows by Ayrshire bulls.

NUTRITION OF DAM

It is often assumed that the size of the calf at birth is influenced directly by the feeding of the dam during gestation. Such an assumption is not borne out by any available data from an investigation of the author. While the data in question were not taken for this special purpose, they have a bearing on the question.

⁷Mumford, F. B. Some Factors Influencing the Weight of Lambs at Birth. Missouri Agr. Exp. Sta. Bul. 53, pp. 3-17. 1901.

One group of Jersey and Holstein heifers used in an investigation previously reported by the author,⁸ were fed a liberal ration from birth to first calving for the purpose of obtaining rapid growth and maintaining a state of flesh far above normal. The ration for the first six months was whole milk with as much grain and alfalfa hay as would be consumed. As a result of this manner of feeding, the Holstein group at 19 months averaged 932 pounds in weight compared to the normal of 715 pounds for animals of this breed at this age. The second group represented the same breeds and received skim milk and legume hay up to the age of six months, and from that age on to the time of first calving, only roughage of good quality. As a result the Holsteins of this group at 19 months averaged 588 pounds in weight, or 127 pounds below the normal weight for the breed, and 344 pounds below the group receiving the liberal ration. A portion of each of these groups was bred to calve at what would be considered an early age for the breed—20 to 22 months for the Jersey and 22 to 24 months for the Holstein. The others were bred to calve at what would be considered a late age, which was 32 to 34 months for the Jerseys and 34 to 36 months for the Holsteins. The data in Table 6 give the weights of the calves by groups and the weights of the dams following calving.

TABLE 6.—INFLUENCE OF NUTRITION OF MOTHER UPON WEIGHT OF CALF AT BIRTH

	Number of animals	Average weight cow following calf birth	Length of gestation period	Average weight of calf
		<i>Pounds</i>	<i>Days</i>	<i>Pounds</i>
Light-fed Jerseys	8	673	281	50
Heavy-fed Jerseys.....	7	936	276	44
Light-fed Holsteins.....	8	855	276	79
Heavy-fed Holsteins....	6	1032	275	81

These data show that the light-fed Jerseys weighing 673 pounds produced calves even a little heavier on the average than those from the heavy-fed group which averaged 263 pounds more in weight. The calves from the light-fed Holsteins averaged only two pounds less than those from the heavy-fed group which averaged 177 pounds more. If the results are expressed in terms of percentage of the weight of the dam, the results are even more striking. The calves from the light-fed Jerseys weighed 7.4 per cent of the weight of

⁸Eckles, C. H. The Ration and Age of Calving as Factors Influencing the Growth and Dairy Characteristics of Cows. Missouri Exp. Sta. Bul. 135, pp. 1-91. 1915.

their dams; the heavy-fed Jerseys 4.7 per cent; and the light-fed Holsteins 7.8 per cent. These data show that the breed is a much stronger factor in determining the size of the calf than the condition of the cow during gestation.

It is a common observation by cattlemen that cows poor in flesh to the point of emaciation, may bear calves of normal size for the breed. The data and observations taken by the author bear out this statement. On the other hand, cows fattened to excess during gestation may have calves small for the breed and lacking in vigor as well. Apparently, it is only extreme cases of poor nutrition or the lack of some constituent in the ration covering a long period of time that may be expected to exert any marked influence upon the size of the calf.

The relatively small influence of the nutrition of the dam upon the development of the foetus may be explained by the dependence of the foetus for nourishment upon the blood stream of the dam and, therefore, only indirectly upon the food of the dam. It is a well-known physiological fact that there is a stronger tendency for the composition of the blood to remain almost constant, even under adverse conditions of nutrition. If a temporary deficit of any constituent occurs in the blood, the shortage is made up by drawing upon the reserve of that constituent already in the body. For this reason the food supply of the foetus remains practically constant regardless of the food of the dam, and in case of a shortage of food during gestation, the mother and not the foetus suffers.

CONCLUSIONS

Breed is the most important factor influencing the weight of calves at birth. On the average, calves of the Jersey breed weigh 55 pounds at birth and represent 6.5 per cent of the weight of the dam. Calves of the Holstein breed, at birth, average 90 pounds in weight and represent 8.0 per cent of the weight of the dams.

Male calves average from five to eight per cent heavier than females.

Calves produced by immature cows, two to four years old, are smaller than those from mature cows, five to ten years old. There is a tendency for cows of advanced age to produce calves rather smaller than those from cows in the prime of life.

The length of the gestation period is not correlated with the size of the calf at birth except in cases of extremely large or small calves, when such a relation usually exists.

The sire apparently has but little influence upon the size of the calf at birth, when both sire and dam are of the same breed, but in case of cross breeding the influence of the sire is evident.

The nutrition of the cow during gestation does not influence the size of the calf at birth to any appreciable extent except possibly under the most extreme conditions continued for a long time.

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THE NORMAL GROWTH OF DAIRY CATTLE

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VARIETAL RESISTANCE AND SUSCEPTIBILITY OF OATS TO POWDERY MILDEW, CROWN RUST, AND SMUTS

GEORGE M. REED*

A well-recognized method of plant-disease control is in the use of varieties of plants which possess a clearly defined resistance to a particular disease. It has long been a matter of observation by plant growers that certain varieties are able to withstand the attacks of a disease which prove to be very serious on other varieties. The discovery and use of such varieties is an obvious way to avoid loss from disease.

The problem of developing resistant varieties is complicated by the fact that physiological host specialization occurs among the parasitic fungi. This phenomenon is of very wide, if not universal, occurrence. The writer⁸¹ has recently summarized the extensive investigations bearing upon this phase of parasitism.

If progress is to be made in breeding disease-resistant varieties it is essential that the resistance or susceptibility toward the parasite be fully determined, and that the possible existence of specialized races of the parasite be worked out. Further, the importance of environmental conditions in the appearance and spread of a disease must be fully recognized; otherwise resistance may be mistaken for mere escape from the disease.

In the present paper the writer brings together a large amount of data on the resistance and susceptibility of species and varieties of *Avena* to the four diseases—powdery mildew, crown rust, loose and covered smut.

The seed used in these experiments were obtained from various sources. A large number were furnished by Doctor Franz Bubak, Director of the Botanical Garden at Tabor, Bohemia. Seed of several varieties were furnished by C. E. Leighty, J. H. Parker, and T. R. Stanton, Office of Cereal Investigations, U. S. Department of Agriculture. Most of the varieties, however, came from the Farm Crops Department of the University of Missouri. I am specially indebted to Dr. W. C. Etheridge for practically a complete set of the varieties described in his Memoir⁸ on the classification of oats.

I am also indebted to Dr. W. E. Maneval, Department of

*Resigned, December, 1918.

Botany, University of Missouri, for looking after the oat-smut plots in 1919. He very kindly supervised the planting and taking of the data and thus made possible the addition of another year's results to the investigations.

All of the experiments with crown rust in 1919 were carried out by Miss Helen Johann, Research Assistant in Botany, University of Missouri. As a result of her careful work the relation of a number of additional varieties of oats were tested with crown rust, as well as further data on varieties tested in previous years.

THE POWDERY MILDEW

Erysiphe Graminis DC. f. *Avenae*.

Marchal²³ was the first to report results showing the physiological specialization of the powdery mildew of grasses. He established the existence of seven specialized races, one of which occurred on three species of *Avena* (*A. fatua*, *A. orientalis*, *A. sativa*) and on *Arrhenatherum elatius*. This race was not able to infect other hosts such as wheat, barley and rye.

Salmon^{23,24} has also carried on some experiments with the oat mildew. Using conidia from *Avena nuda* he infected *A. nuda*, *A. brevis* and *A. sativa*; conidia from *A. sterilis* infected *A. pratensis* and *A. sativa*; and conidia from *A. sativa* infected *A. sativa*, *A. brevis*, *A. nuda*, *A. orientalis*, *A. sterilis* and *A. strigosa*. Salmon was unable to transfer the oat mildew to twelve other grasses. He also failed to transfer the oat mildew to *Arrhenatherum elatius*, which Marchal listed as a host for the same mildew as occurs on *Avena*.

The writer³⁰ has previously reported the results of extensive experiments with the powdery mildew of oats. The data recorded included tests with forty-one varieties belonging to seventeen species of the genus *Avena*. Of these varieties, thirty-two were infected in one hundred per cent of the trials, and, in seven additional varieties, the percentage of infection varied from fifty to ninety-eight per cent. Two species, *Avena bromoides* and *A. sempervirens*, gave negative results; in both cases, however, the number of experiments was small. Positive results were obtained with the following: *Avena brevis*, *A. fatua*, *A. fatua* var. *glabrata*, *A. ludoviciana*, *A. nuda*, *A. nuda* var. *chinensis*, *A. nuda* var. *elegantissima*, *A. planiculmis*, *A. pratensis*, *A. pubescens*, *A. sativa* (sixteen varieties), *A. sativa orientalis* (six varieties), *A. strigosa* and *A. sulcata*. In practically every case the commonly cultivated varie-

ties of oats gave a very high percentage of infection. In fact none of them gave any indication of resistance to the powdery mildew.

The tall meadow oat grass, *Arrhenatherum elatius*, was infected to a certain extent. The oat mildew can therefore be transferred to this grass. No infection occurred, however, when the oat mildew was sown on *Holcus lanatus*, *Hordeum vulgare* and *Triticum vulgare*.

These results confirm the work of Marchal and Salmon as to the existence of a well-defined specialized race of *Erysiphe graminis* restricted to the species and varieties of the genus *Avena*, altho it may also infect *Arrhenatherum elatius*. It is also evident that practically all species and varieties of *Avena* are highly susceptible to this specialized race of *Erysiphe graminis*.

A large number of additional varieties, belonging to several different species, have been tested as to their susceptibility to the powdery mildew of oats. These experiments have been conducted in the same manner as previously. The plants inoculated were from six to fifteen days old, the first leaf usually being from one to five centimeters long. The spores were dusted on by shaking heavily infected plants over the seedlings. The plants were then kept under glass chambers. Infection was generally evident after three to five days and, at the end of a week, abundant production of conidia occurred on all susceptible hosts.

The original cultures of the oat mildew were obtained from Dr. R. A. Harper, Columbia University. He very kindly furnished cultures on living oat plants on two different occasions. The cultures were continued on oats by keeping a succession of oat seedlings available for inoculation. Fresh stock cultures were started every two to four weeks and these served as a source for an abundant supply of conidia.

During the fall, winter and spring months no difficulty was encountered in keeping on hand excellent stock cultures. In the late spring, however, it became difficult to do so and only by the most careful methods was it possible to keep the oat mildew throughout the summer months.

The results of the writer's work with the powdery mildew of oats are briefly summarized in Table 1. The earlier published results are brought together in the table with those here published for the first time.

TABLE 1.—RESULTS OF INOCULATIONS WITH CONIDIA OF *Erysiphe Graminis* DC.
FROM *Avena sativa* L.

Host	Seed No.	Total No. Exp.	No. Plants Inoc.	No. Plants Infected	Per cent Infected
<i>Avena brevis</i> Roth.*	1	21	218	214	98.1
<i>Avena brevis</i> Roth.	77	1	10	10	100
<i>Avena brevis</i> Roth.	134	6	90	90	100
<i>Avena brevis</i> Roth. ¹	135	7	85	75	88.2
<i>Avena bromoides</i> Gouan*	2	7	30	0	0
<i>Avena fatua</i> L.*	78	13	90	90	100
<i>Avena fatua</i> L.	136	6	55	55	100
<i>Avena fatua</i> L.—					
var. <i>glabrata</i> *	79	4	17	17	100
var. <i>glabrata</i> ²	137	6	91	91	100
var. <i>glabrata</i> ³	138	4	62	62	100
<i>Avena nuda</i> L.*	25	8	48	48	100
<i>Avena nuda</i> L.—					
var. <i>chinensis</i> *	30	7	42	42	100
var. <i>elegantissima</i>	26	6	30	30	100
<i>Avena planiculmis</i> Schrad.*	73	6	48	48	100
<i>Avena pratensis</i> L.*	68	8	61	39	63.9
<i>Avena pubescens</i> Huds.*	6	7	52	34	65.3
<i>Avena purpurea</i> Gueldenst.*	81	4	12	12	100
<i>Avena sativa</i> L.* ⁴		3	17	17	100
<i>Avena sativa</i> L.—					
var. <i>aurea</i> Kcke.*	7	21	205	191	93.1
var. Awnless Probsteyer....	114	5	73	73	100
var. Belyak	115	4	61	61	100
var. Black Diamond	116	4	72	72	100
var. Black Mesdag	117	4	72	72	100
var. Black Norway	118	4	56	56	100
var. <i>brunnea</i> Kcke.*	8	6	50	50	100
var. Canadian	119	4	57	57	100
var. C. I. 606	127	4	71	71	100
var. Culberson	120	4	67	67	100
var. Green Russian	121	4	87	87	100
var. <i>grisea</i> Kcke.*	41	6	62	62	100
var. Joannette	125	4	81	81	100
var. Kherson*	94	2	13	13	100
var. <i>Krausei</i> Kcke.*	9	14	110	105	95.4
var. <i>Montana</i> Alef.*	10	8	72	72	100
var. North Finnish	123	4	68	68	100
var. <i>mutica</i> Alef.* ⁵		50	678	678	100
var. <i>nigra</i> Kr.* ⁶		17	210	210	100
var. <i>prae-gravis</i> Kr.* ⁷		20	256	256	100

TABLE 1.—RESULTS OF INOCULATIONS WITH CONIDIA OF *Erysiphe Graminis* DC.
FROM *Avena sativa* L. (Continued)

Host	Seed No.	Total No. Exp.	No. Plants Inoc.	No. Plants Infected	Per cent Infected
<i>Avena sativa</i> L.—					
var. Scottish Chief	124	4	54	54	100
var. Silvermine*	101	9	92	92	100
var. Silvermine	101	1	50	50	100
var. Tobolsk	122	5	108	108	100
var. <i>trisperma</i> Schubl.*....	64	6	77	77	100
var. Victor	126	6	97	97	100
var. White Tartar*	106	21	348	348	100
<i>Avena sativa orientalis</i> L.* ⁴		3	13	13	100
<i>Avena sativa orientalis</i> L.—					
var. Black Tartarian	108	4	64	64	100
var. <i>flava</i> Kcke.*	31	7	45	45	100
var. Garton 748	109	4	68	68	100
var. Green Mountain	110	4	59	59	100
var. <i>mutica</i> Kcke.*	32	6	40	40	100
var. <i>obtusata</i> Alef.*	33	10	69	69	100
var. <i>pugnax</i> Alef.*	65	7	84	84	100
var. <i>setosa</i> *	14	11	98	98	100
var. Sparrowbill	111	5	75	75	100
var. Storm King	112	4	42	42	100
var. <i>tartarica</i> Ard.*	34	29	274	268	97.8
var. Tartar King	113	5	72	72	100
var. <i>tristis</i> Alef.*	40	8	65	65	100
<i>Avena sempervirens</i> Vill.*	71	2	7	0	0
<i>Avena sterilis</i> L.* ⁴	27, 28	23	197	197	100
<i>Avena sterilis</i> L.* ⁴	128	4	42	42	100
<i>Avena sterilis</i> L.—					
var. Burt*	67	8	95	95	100
var. Burt	74	2	24	24	100
var. Early Ripe*	75	4	37	37	100
var. Early Ripe	75	2	30	30	100
var. Fulghum	129	4	78	78	100
var. <i>ludoviciana</i> *	80	6	43	43	100
var. <i>nigra</i>	130	4	39	39	100
var. Red Rustproof*	98	3	22	22	100
var. Red Rustproof	131	4	74	74	100
var. Selection	132	4	75	75	100
<i>Avena strigosa</i> Schreb.*	29	9	88	88	100
<i>Avena strigosa</i> Schreb.* ⁸	76	6	53	27	50.9
<i>Avena strigosa</i> Schreb.	76	2	8	5	62.5
<i>Avena strigosa</i> Schreb.	133	6	117	117	100
<i>Avena sulcata</i> F. Gay*	72	7	36	36	100

TABLE 1.—RESULTS OF INOCULATIONS WITH CONIDIA OF *Erysiphe Graminis* DC. FROM *Avena sativa* L. (Continued)

Host	Seed No.	Total No. Exp.	No. Plants Inoc.	No. Plants Infected	Per cent Infected
<i>Arrhenatherum elatius</i> (L.)					
Beauv.*		25	450	63	14
<i>Holcus lanatus</i> L.*		4	24	0	0
<i>Lolium multiflorum</i> Lam.	1a	2	90	0	0
<i>Lolium perenne</i> L.	3a	2	80	0	0
<i>Hordeum vulgare</i> L.*		6	92	0	0
<i>Triticum vulgare</i> Vill.*		6	112	0	0

*The star indicates that these results were published in Missouri Agr. Exp. Sta. Research Bulletin 23, 1916.

¹Late maturing strain.

²Grey to black seeded strain.

³Yellow seeded strain.

⁴Variety not known.

⁵Includes tests with eighteen collections of this variety, mainly from different localities in Europe.

⁶Includes tests with four collections of this variety, mainly from different localities in Europe.

⁷Includes tests with four collections of this variety, mainly from different localities in Europe.

⁸This was received under the name of *Avena barbata*.

Altogether ninety-eight different varieties or strains have been tested. Of these eighty-eight gave one hundred per cent infection; eight gave fifty to ninety-eight per cent and only two gave negative results. Practically every variety and strain of *A. brevis*, *A. nuda*, *A. fatua*, *A. sativa*, *A. sativa orientalis*, *A. sterilis* and *A. strigosa* were fully infected. An occasional plant in some experiments may have escaped infection. *Avena pratensis* and *A. pubescens* have given a somewhat low percentage of infection. The two species, *A. bromoides* and *A. sempervirens*, proved free from infection. Unfortunately the supply of seed was too small to make a large number of experiments.

The oat mildew, to some extent at least, is capable of passing over on to the tall meadow oat 'grass' (*Arrhenatherum elatius*), sixty-three plants out of four hundred and fifty inoculated becoming infected. It does not infect *Holcus lanatus*, *Lolium multiflorum*, *L. perenne*, *Hordeum vulgare* nor *Triticum vulgare*.

It is clear from the foregoing results that, while the oat mildew is highly specialized to the genus *Avena* and *Arrhenatherum elatius*, it is capable of developing luxuriantly on practically all common species and varieties of *Avena*. One is impressed with the sharp limitation of the race to this genus, except as noted, and

at the same time, its vigorous development on the species and varieties of this genus. *Avena pratensis*, *A. pubescens*, and *Arrhenatherum elatius* do not appear to be infected so readily, nor is the growth of the mycelium and production of conidia so abundant on these hosts.

CROWN RUST

Puccinia Coronata Corda.

Crown rust is of very general occurrence thruout the oat-growing sections of the country, east of the Rocky Mountain region. Thruout this section the disease is more or less prevalent every season. Some years it is responsible for very serious damage to the oat crop. Its ravages are generally greater in the southern section as compared with the northern. The introduction of winter oats in the South, which mature sufficiently early, in order to escape the damage done by the disease, is one method of avoiding the losses. In the spring oats section early maturing varieties largely escape the heavy loss. It is, however, highly desirable to secure, if possible, resistant varieties in order to avoid the damage to the oat crop.

Crown rust occurs not only on the species and varieties of *Avena*, but on a large number of other grasses as well. The fungus is, further, heteroecious, the aecidial stage occurring on various species of *Rhamnus*. It is not at all clear, as yet, the role played by the aecidial host in epidemics of this disease.

Extensive work has been done with the crown rust of grasses from the standpoint of host specialization. The writer²¹ has recently summarized the work of Eriksson^{5|6|7}, Klebahn^{14|19}, Muhlethaler^{24|25}, and others along this line. There appears to be in Europe a series of specialized races based upon the aecidial host and, within these races, still others based upon the capacity of the uredospores to infect the various grass hosts.

Carleton⁸ has tested the host relations of crown rust on oats and certain grasses. He reports that uredospores from *Avena sativa* can infect *Avena sativa patula*, *A. sativa orientalis*, *A. sativa nuda*, *A. fatua*, *A. pratensis*, *Alopecurus alpestris*, *Aira caespitosa*, *Anthoxanthum odoratum*, *Brizopyron siculum*, *Dactylis glomerata*, *Eatonia* sp. indet., *Festuca* sp. indet., *Holcus mollis*, *Koeleria cristata*, *Phalaris arundinacea*, *Phleum asperum*, *Ph. pratense*, *Poa annua*, *Polypogon monspeliensis* and *Trisetum subspicatum*. He also infected *Avena sativa* and *Dactylis glomerata* with uredo-

spores from *Phalaris caroliniana*. Further, uredospores from *Arrhenatherum elatius* infected *Avena sativa*.

Treboux^{27|28}, in southern Russia, found that aecidiospores from *Rhamnus cathartica* infected fifty-one species of grasses belonging to twenty-eight genera. Neither Carleton nor Treboux have found the high degree of specialization reported by the European workers.

Vavilov^{29|40} has reported extensive observations as to the susceptibility and resistance of oat varieties to *Puccinia coronata* f. *avenae* and also to *P. graminis* f. *avenae*. In his studies he used three hundred and fifty pure lines belonging to twenty-four varieties based on Kornicke's classification. These varieties were distributed among eight species of *Avena*.

Most of these pure lines were highly susceptible to crown rust. This was specially true of the varieties of *Avena diffusa* (*A. sativa*) and *A. orientalis* most widely used in cultivation, notably the white and yellow seeded sorts. The wild forms of cultivated oats, viz., *A. fatua*, *A. ludoviciana* and *A. sterilis*, also proved highly susceptible.

The most resistant forms belonged to varieties of *A. diffusa* (*A. sativa*) with brown and grey seeds. *Avena strigosa*, *A. brevis* and *A. nuda* var. *biaristata* also proved fairly resistant. In all, twenty-four pure lines possessed considerable resistance to crown rust.

Vavilov's work consisted of field observations during the two years 1911 and 1912. His most susceptible varieties were characterized by the appearance of uredo pustules on both lower and upper leaves and, later, by teleuto pustules. His resistant forms, on the other hand, had a few uredo pustules on the lower leaves only, accompanied by more or less flecking of the leaves; no teleuto pustules appeared.

As compared with crown rust only two pure lines gave any well-defined resistance to stem rust—*Puccinia graminis*; these lines belonged to *A. diffusa* var. *brunnea* and *A. diffusa* var. *montana*. All the other pure lines proved to be highly susceptible to the stem rust.

Parker²⁸ has also studied the behavior of oat varieties to both *Puccinia graminis* and *P. coronata* under greenhouse experimental conditions. He inoculated his plants at two stages of development—in the young seedling stage and at the time when the plants were ready to head out.

Of the one hundred and twenty-two varieties or strains used eighty proved to be entirely susceptible to both rusts in both

stages of development. In fact only two varieties, White Tartarian and Ruakura Rustproof, gave any evidence of resistance to stem rust. On the other hand, a considerable number of strains or varieties showed more or less resistance to the crown rust. Nearly all of these belonged to the *Avena sterilis* group. The resistance, further, was more marked in the later stage of growth than in the seedling stage. As evidence of resistance such points as a longer incubation period, the small size of the uredo pustules and the formation of flecks on the leaves were taken. Parker also emphasizes the fact that teleuto pustules did not appear following abundant production of uredospores. He records the appearance of teleutospores on leaves of seedlings on which uredospores were not produced normally and which gave the other evidences of resistance. It may be noted in passing that the appearance or non-appearance of teleuto pustules is given a different significance by Parker and Vavilov.

Hoerner¹¹ has recently reported the possible existence of specialized races of crown rust on varieties of *Avena*. He used cultures of crown rust obtained from a number of localities. He distinguishes four races on the basis of their action on Ruakura Rustproof and Green Russian: (1) Infects both normally; (2) infects both weakly; (3) infects Ruakura weakly and Green Russian normally; (4) infects Ruakura normally and Green Russian weakly.

For several years the writer has carried out inoculation experiments with the crown rust of oats. Cultures were usually obtained in the fall on volunteer oats and carried thru the winter by keeping a supply of seedling oats available and transferring the uredospores to these. Such stock cultures were started anew every three to four weeks.

In the experiments seedlings were used. These were grown in small pots, five to twenty plants in each, until the first green leaf was about two to five centimeters long. The plants were inoculated by dusting over them a large number of uredospores from the stock cultures. In this way large numbers of uredospores fell on the leaves.

The inoculated plants were then placed under bell-jars or larger glass boxes and given ample water and aeration. These conditions proved very favorable for infection. No special effort was made to insure thoro wetting of the leaves as this proved quite unnecessary in order to secure abundant infection.

In six to seven days infection was generally evident by the appearance of large numbers of small yellow-greenish areas on the

inoculated leaves. Two or three days later uredospore pustules pushed through at these points. Generally the pustules broke open and shed uredospores nine days after inoculation.

In most experiments the results with the different varieties were compared carefully with those observed on control plants of the same variety as that from which the uredospores were taken for inoculation.

Most of the experiments were carried out during the fall, winter and spring months of 1916-1917 and 1918-1919. During 1916-1917, W. E. Brentzel² carried out independently a large number of tests with several varieties. The 1918-1919 results were very largely obtained by Miss Helen Johann.

The results of these experiments are summarized in Table 2.

TABLE 2.—RESULTS OF INOCULATIONS WITH UREDOSPORES OF *Puccinia coronata* CORDA FROM *Avena sativa* L.

Host	Seed No.	Total No. Exp.	No. Plants Inoc.	No. Plants Infected	Per cent Infected
<i>Avena brevis</i> Roth.* ¹	1	12	119	97	81.5
<i>Avena brevis</i> Roth.	77	11	163	148	90.7
<i>Avena brevis</i> Roth.*	77	3	30	30	100
<i>Avena brevis</i> Roth.	134	4	43	43	100
<i>Avena brevis</i> Roth.	135	4	26	11	42.3
<i>Avena brevis</i> Roth.	142	6	55	55	100
<i>Avena fatua</i> L.	136	3	21	21	100
<i>Avena fatua</i> L.	143	8	69	67	97.1
<i>Avena fatua</i> L.—					
var. <i>glabrata</i> *	78	3	11	11	100
var. <i>glabrata</i> *	79	5	29	29	100
var. <i>glabrata</i>	137	4	26	26	100
var. <i>glabrata</i>	138	6	72	72	100
<i>Avena nuda</i> L.	25	11	128	128	100
<i>Avena nuda</i> L.*	25	1	10	10	100
<i>Avena nuda</i> L.	144	8	36	36	100
<i>Avena nuda</i> L.—					
var. <i>chinensis</i>	30	8	86	81	94.1
var. <i>chinensis</i> *	30	6	60	50	83.3
var. <i>elegantissima</i>	26	9	79	74	93.6
var. <i>elegantissima</i> *	26	3	30	30	100
<i>Avena sativa</i> L.—					
var. American Banner	82	4	45	45	100
var. American Banner*....	82	3	30	30	100
var. <i>aristata</i> *	42	3	30	30	100
var. <i>aurea</i> *	7	17	153	151	98.6

TABLE 2.—RESULTS OF INOCULATIONS WITH UREDOSPORES OF *Puccinia coronata* CORDA FROM *Avena sativa* L. (Continued)

Host	Seed No.	Total No. Exp.	No. Plants Inoc.	No. Plants Infected	Per cent Infected
<i>Avena sativa</i> L.—					
var. Awnless Probsteier....	114	2	16	16	100
var. Belyak	115	3	33	33	100
var. Big Four*	83	3	30	30	100
var. Black Diamond	116	4	36	36	100
var. Black Mesdag	117	2	30	30	100
var. Black Norway	118	2	15	15	100
var. <i>brunnea</i>	8	2	25	25	100
var. <i>brunnea</i> *	8	6	60	60	100
var. Canadian	119	4	57	57	100
var. C. I. 602	145	8	67	67	100
var. C. I. 603	146	9	77	77	100
var. C. I. 606	127	4	54	54	100
var. C. I. 606	147	8	82	82	100
var. C. I. 620	148	7	20	20	100
var. Culberson	120	4	47	47	100
var. Currell No. 6*	87	3	27	27	100
var. Czar of Russia	85	2	28	28	100
var. Czar of Russia*	85	3	30	30	100
var. Danish Island	149	6	29	29	100
var. Early Champion	150	8	90	90	100
var. Early Dakota	151	8	64	64	100
var. Early Gothland	152	8	63	63	100
var. Early Illinois*	86	3	30	30	100
var. Garton	153	8	50	50	100
var. Golden Drop	154	6	44	37	84.0
var. Great Dakota*	89	3	30	30	100
var. Green Russian*	90	3	30	30	100
var. Green Russian	121	2	33	33	100
var. Irish Victor	155	6	51	43	84.3
var. Japan 144	93	3	30	30	100
var. Japan Selection	156	4	27	23	85.1
var. Joannette	125	4	46	46	100
var. June	157	8	61	51	83.6
var. Kherson*	94	3	30	30	100
var. Kherson	158	6	73	73	100
var. Kherson Selection....	159	8	82	71	86.5
var. <i>Krausei</i> *	9	6	51	51	100
var. Lincoln*	95	3	30	30	100
var. Lincoln	160	8	44	41	93.1
var. Monarch	161	6	44	44	100
var. Monarch Selection....	162	6	38	37	97.3
var. <i>montana</i> *	10	3	30	28	93.3

TABLE 2.—RESULTS OF INOCULATIONS WITH UREDOSPORES OF *Puccinia coronata* CORDA FROM *Avena sativa* L. (Continued)

Host	Seed No.	Total No. Exp.	No. Plants Inoc.	No. Plants Infected	Per cent Infected
<i>Avena sativa</i> L.—					
var. <i>mutica</i> *	11	3	19	19	100
var. <i>mutica</i> *	42	6	57	51	89.4
var. <i>mutica</i> *	43	6	44	33	75.0
var. <i>mutica</i> *	45	3	30	30	100
var. <i>mutica</i>	51c	1	10	10	100
var. National*	96	3	29	18	62.0
var. <i>nigra</i> *	12	6	58	58	100
var. <i>nigra</i> *	59	3	13	13	100
var. North Finnish	123	2	27	27	100
var. Old Island Black	163	8	83	83	100
var. <i>praegravis</i> *	13	6	55	55	100
var. <i>praegravis</i> *	61	6	60	60	100
var. Ruakura Rustproof....	266	8	93	93	100
var. Scottish Chief	124	2	25	25	100
var. Sensation*	99	3	30	30	100
var. Silvermine	101	8	99	99	100
var. Silvermine*	101	3	30	30	100
var. Silvermine	164	8	44	42	95.4
var. Silvermine Selection	165	8	58	58	100
var. Sixty-Day	166	8	89	89	100
var. Sixty-Day Selection	167	8	61	59	96.7
var. Swedish Select	168	8	27	27	100
var. Tobolsk	122	2	20	20	100
var. <i>trisperma</i>	64	6	50	50	100
var. <i>trisperma</i> *	64	6	47	47	100
var. Victor	126	4	51	51	100
var. White Russian	104	2	20	20	100
var. White Russian*	104	3	30	30	100
var. White Schoenen	105	2	20	13	65
var. White Schoenen*	105	3	30	30	100
var. Wide Awake	107	1	10	10	100
var. Wide Awake*	107	3	30	30	100
var. Winter Turf	169	8	40	40	100
<i>Avena sativa orientalis</i> L.—					
var. Black Tartarian	108	4	29	29	100
var. <i>flava</i>	31	2	20	17	85
var. <i>flava</i> *	31	3	30	30	100
var. Garton 585	170	7	34	30	88.2
var. Garton 748	109	3	26	26	100
var. Garton 784	171	5	14	14	100
var. Garton's Black*	88	3	30	30	100

TABLE 2.—RESULTS OF INOCULATIONS WITH UREDOSPORES OF *Puccinia coronata* CORDA FROM *Avena sativa* L. (Continued)

Host	Seed No.	Total No. Exp.	No. Plants Inoc.	No. Plants Infected	Per cent Infected
<i>Avena sativa orientalis</i> L.—					
var. Garton Gray	172	6	19	19	100
var. Golden Giant	173	6	47	47	100
var. Green Mountain	110	4	44	44	100
var. <i>mutica</i> *	32	3	30	25	83.3
var. <i>obtusata</i> *	4	3	26	19	73.0
var. <i>obtusata</i> *	33	9	89	84	94.3
var. <i>pugnax</i>	65	2	22	22	100
var. <i>pugnax</i> *	65	9	76	76	100
var. <i>setosa</i> *	14	6	50	50	100
var. Sparrowbill*	102	3	30	28	93.3
var. Sparrowbill	111	3	28	28	100
var. Storm King	112	3	23	23	100
var. Tartar King	113	2	12	12	100
var. <i>tartarica</i>	5	2	24	24	100
var. <i>tartarica</i> *	5	6	60	57	95
var. <i>tartarica</i> *	34	6	58	46	82.7
var. <i>tristis</i> *	40	15	146	136	93.1
var. White Tartar	174	8	63	62	98.4
<i>Avena sterilis</i> L.*	27	9	90	63	70
<i>Avena sterilis</i> L.	28	4	22	17	77.7
<i>Avena sterilis</i> L.*	28	6	52	47	90.3
<i>Avena sterilis</i> L.	128	12	88	68	77.2
<i>Avena sterilis</i> L.—					
var. Burt	67	4	55	49	89.0
var. Burt*	67	6	60	60	100
var. Burt	74	8	93	75	80.6
var. Burt*	74	3	30	30	100
var. Burt	175	8	58	58	100
var. Burt	254	8	85	85	100
var. Burt	255	8	88	88	100
var. Early Ripe	75	6	70	70	100
var. Early Ripe*	75	6	60	60	100
var. Fulghum	129	6	76	76	100
var. Fulghum	257	8	95	95	100
var. Italian Rustproof	259	6	70	70	100
var. Italian Rustproof.....	260	6	62	62	100
var. <i>ludoviciana</i>	80	5	66	21	31.8
var. <i>ludoviciana</i> *	80	6	60	60	100
var. <i>ludoviciana</i>	176	2	14	14	100
var. <i>nigra</i>	130	11	49	39	79.5
var. Red Rustproof*	98	3	29	29	100
var. Red Rustproof	131	6	55	55	100

TABLE 2.—RESULTS OF INOCULATIONS WITH UREDOSPORES OF *Puccinia coronata* CORDA FROM *Avena sativa* L. (Continued)

Host	Seed No.	Total No. Exp.	No. Plants Inoc.	No. Plants Infected	Per cent Infected
<i>Avena sterilis</i> L.—					
var. Selection	132	4	53	53	100
var. Turkish Rustproof	267	6	71	71	100
var. Turkish Rustproof	268	6	68	68	100
<i>Avena strigosa</i> Schreb.	29	8	88	73	82.9
<i>Avena strigosa</i> Schreb.*.....	29	3	30	30	100
<i>Avena strigosa</i> Schreb. ²	76	2	36	36	100
<i>Avena strigosa</i> Schreb.	133	7	74	71	95.9
<i>Arrhenatherum elatius</i> (L.) Beauv.		3	60	0	0
<i>Lolium multiflorum</i> Lam.....	1a	6	200	0	0
<i>Lolium perenne</i> L.....	3a	6	200	1	0.5

¹The star indicates that the results were obtained by W. E. Brentzel (2) and described in his thesis.

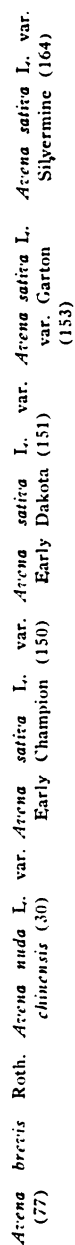
²This was received under the name of *Avena barbata*.

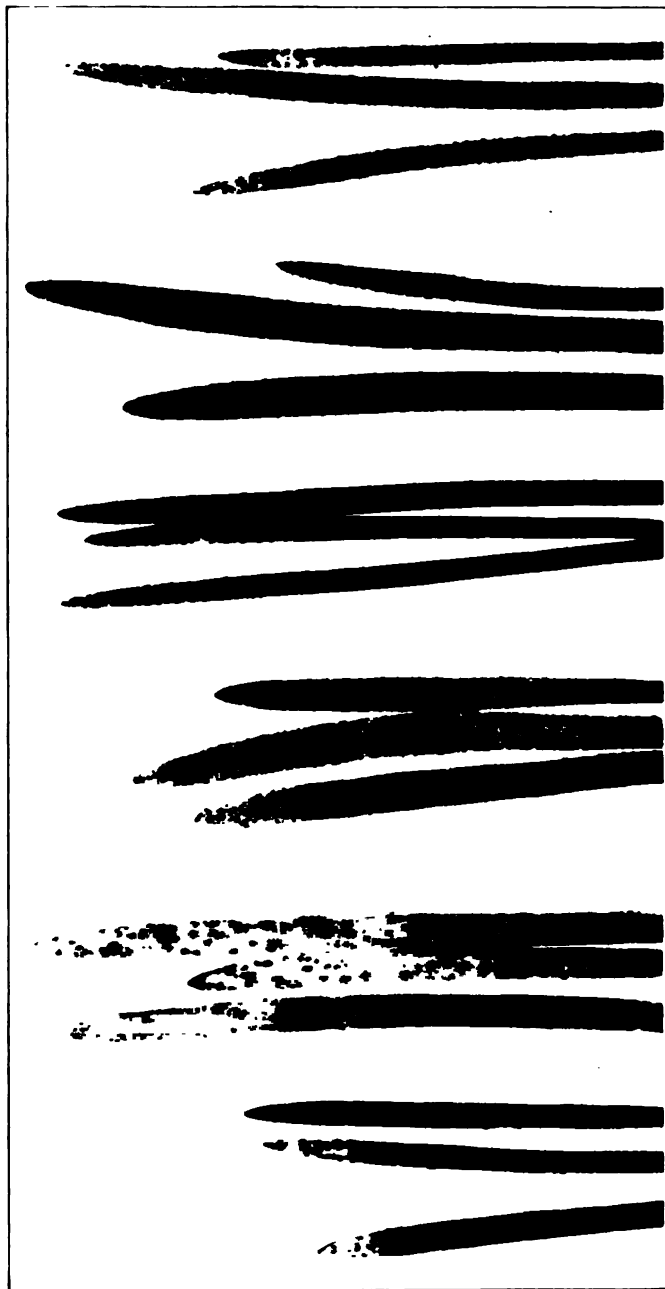
In Table 2 are recorded the results with one hundred and thirty-two strains or varieties belonging to seven species of *Avena*. Each variety was used in two or more experiments. In several cases the same variety was tested in different years as well as at different times during a season.

The table includes the results of Brentzel's experiments with fifty-six strains or varieties belonging to seven species. Twenty-one varieties were tested independently by Brentzel and the writer. The methods used, however, were essentially the same.

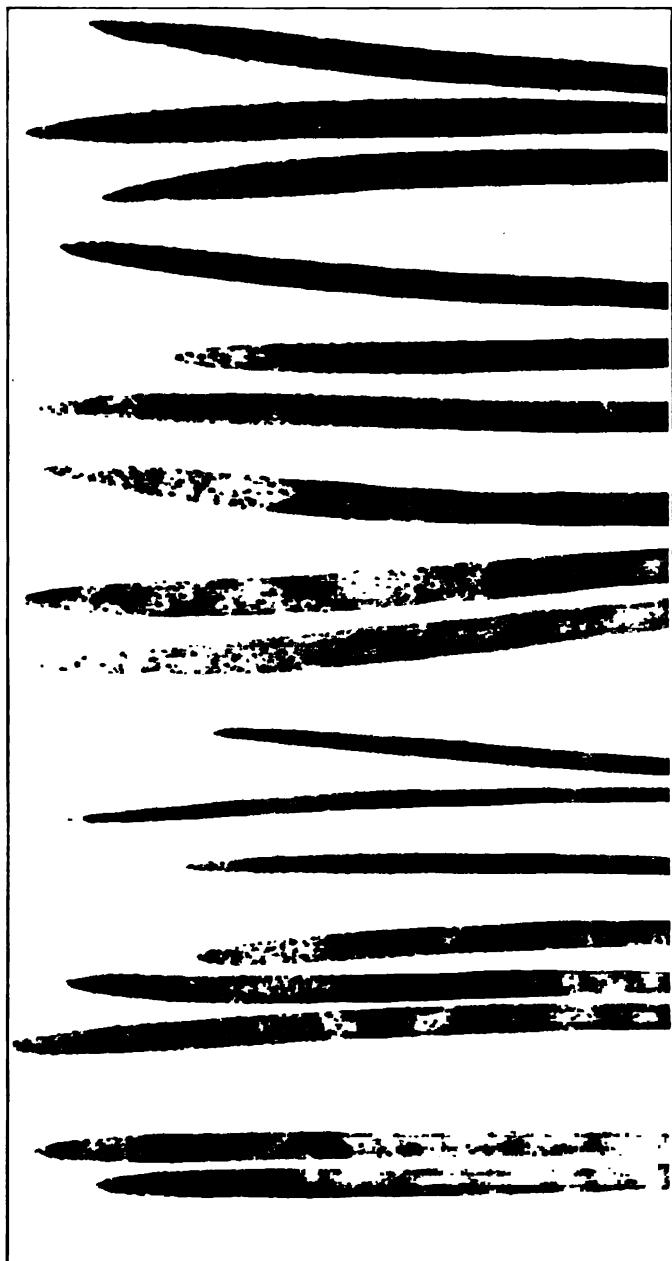
In recording the results for each individual experiment with a variety a direct comparison was made with well-proved susceptible varieties. In most cases the stock cultures were kept on the same host thruout the season and seedlings of this variety were inoculated in most of the series of experiments, and thus served as a direct basis for comparison. In this way the number of pustules which developed, their size, the time required for the pustules to break open and other points were carefully compared on the different plants.

Due to the very heavy inoculation a large number of uredo pustules appeared on the leaves. These pustules were usually small and round but, where close together, more or less coalesced and became irregular in shape. When fewer pustules appeared

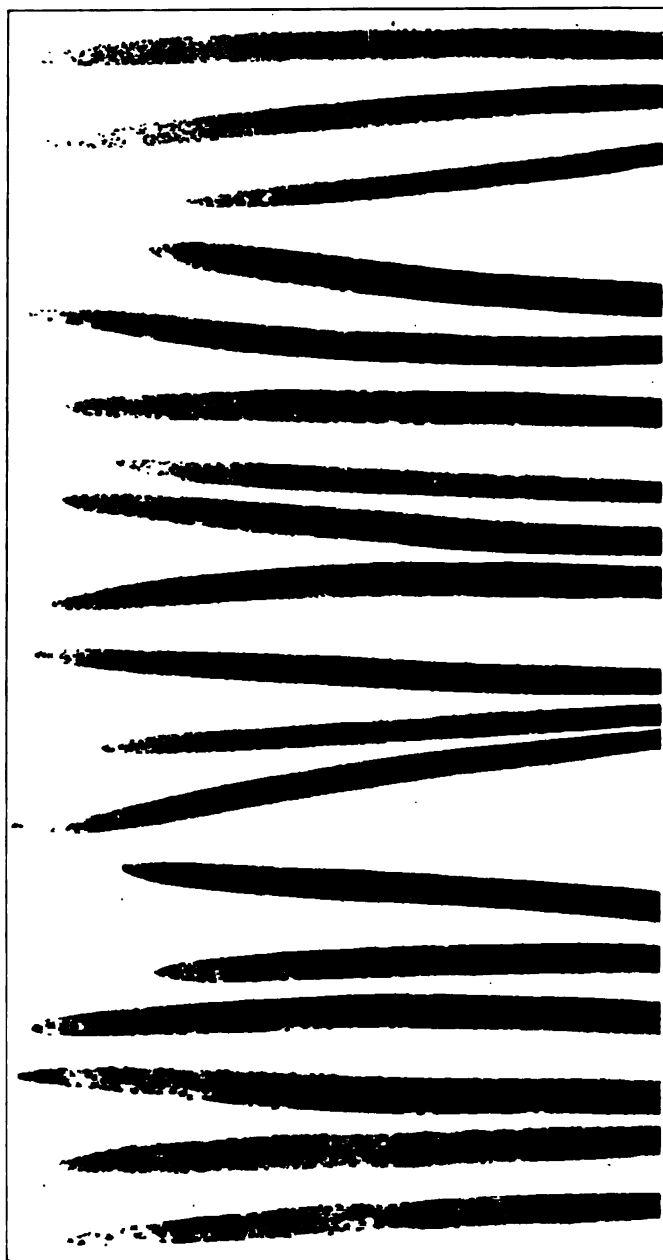




Avena sativa L. var. Sixty-Day (166)
Avena sativa L. var. Sixty-Day Selection (167)
Avena sativa L. var. Swedish Select (168)
Avena sativa L. var. Winter Turf (169)
Avena sativa orien- talis L. var. Gar- ton 585 (170)
Avena sativa orien- talis L. var. White Tartar (174)



Avena fatua L. (143)
Avena nuda L. var. *elegantissima* (26)
Avena strigosa Schreb. (29)
Avena sterilis L. var. *Burt* (175)
Avena sterilis L. var. *Burt* (254)
Avena sterilis L. var. *Fulghum* (257)



Avena sterilis L. var. *Avena sterilis* L. var. *Avena sterilis* L. var. *Avena sativa* L. var.
Fulgum (257) Italian Rustproof (260) Turkish Rustproof (268) Ruakura Rustproof (260)

on the leaves these were often larger and generally surrounded by a clearly defined light-greenish area.

In several cases, in different experiments, a "flecking" of the leaves occurred, accompanied by relatively few open pustules. This was observed in individual experiments with a considerable number of varieties. In other experiments with the same variety, however, no such flecking was observed; instead large numbers of pustules broke open at the end of the usual incubation period. Such "flecking" did not appear to be characteristic of any variety in all the experiments in which it was used.

In no case did teleuto pustules appear on any of the plants which were kept under observation for two to three weeks after the first appearance of the uredospores. Teleuto pustules were observed only once or twice in the stock cultures which were frequently kept for several weeks after they first became infected.

The incubation period was practically the same in every case. The uredo pustules broke open with great regularity nine days after the plants were inoculated. There were variations from this in different experiments. Only one variety, however, showed any consistent lengthening of the incubation period, namely, *Avena sativa* var. *trisperma*. The uredo pustules on these plants usually broke open one or two days later than on the other varieties inoculated at the same time. In some cases, however, there was no apparent lengthening of the incubation period in this variety.

On examining this table one of the most striking things is the occurrence of one hundred per cent infection with a very large number of varieties. Nine-two varieties were fully infected in every experiment. In all these cases uredo pustules, in greater or less number, broke open on every leaf inoculated. In thirty-four additional varieties infection occurred on seventy-five to ninety-nine per cent of the plants inoculated. In these cases infection failed on one or more plants in a particular experiment or, rarely, negative results were obtained on all plants in one series. Five varieties had fifty to seventy-four per cent of the inoculated plants infected. The remaining variety, a strain of *Avena brevis* (No. 135), gave forty-two per cent infection, eleven out of twenty-six inoculated plants developing typical uredo pustules. A larger number of trials with this strain is desirable to determine whether there is a marked resistance to the rust or whether the low percentage of infection was due to ineffective inoculation. The number of pustules and their general character was the same on the infected

plants as on the completely infected plants of other varieties used in the same experiment.

The number of pustules which developed on the inoculated varieties varied somewhat in the different experiments. This, in large part at least, was due to variation in the number of viable uredospores sown on the leaves. In general there was as much variation in the number of pustules on the varieties used as checks as on any other.

A smaller number of pustules appeared on one strain of *Avena brevis* (No. 1) in a number of experiments. In other experiments, however, there was no apparent difference in this or other respects. As already noted the incubation period was generally longer with *Avena sativa* var. *trisperma*. In this variety also fewer pustules appeared on the inoculated leaves in several experiments than on most of the other varieties used in the same series of experiments. However, all the plants inoculated by both Brentzel and the writer showed open pustules of uredospores.

No experiments were conducted with older plants. Brentzel, however, studied the development of the rust on older plants of a number of varieties. These were planted in a cold frame in early spring and allowed to develop to maturity. The plants were inoculated two or three different times. Later the amount of rust which developed on the leaves was compared. The number of uredo pustules varied considerably. The strain of *Avena brevis* (No. 1), which frequently showed less rust in the greenhouse, had slightly less than most of the varieties. There was also noticeably less rust on *Avena sativa* var. *trisperma* as compared with the others.

The characteristics of the pustules, their number, size, shape, etc., are well shown in the accompanying figures. Considerable differences are to be noted in these respects. In a few cases infected plants of the same variety from different experiments are illustrated. On the same variety, for example, *Fulghum*, *Italian Rustproof*, *Ruakura Rustproof* and *Turkish Rustproof*, we sometimes find a very large number of small pustules and, again, a smaller number of somewhat larger pustules. In the latter case the characteristic light-green areas surrounding the cluster of uredospores are quite evident.

A few results are recorded in which uredospores from oats were sown on other grasses. No infection was obtained on *Arrhenatherum elatius* nor *Lolium multiflorum*. A single plant of *Lolium perenne*, in about two hundred inoculated, developed a small uredospore pustule.

THE OAT SMUTS

Ustilago Avenae (Pers.) Jens. and *Ustilago Levis* (K. & S.) Magn.

There are two distinct species of smuts which attack oats—the loose smut, *Ustilago avenae*, and the covered or hidden smut, *Ustilago levis*. The life histories of these two species are similar in all essential respects. In part they may be distinguished by their pathological effects upon the host. The loose smut causes a very complete destruction of the kernel and enclosing glumes. Soon after the oat panicle emerges from the boot the black, dusty spores, with the remnants of the host tissue, are disseminated, leaving a naked, slightly branched panicle. The covered, or hidden smut, also causes the more or less complete destruction of the kernel. The glumes, however, are less involved. They remain more or less persistent and conceal the smut spore masses. The bases of the glumes are, however, more or less attacked and the tissues show blackish, due to the presence of the fungous spores among the host cells.

Frequently it is difficult to distinguish by macroscopic observations between the two smuts. Sometimes the lower spikelets show the external features of *Ustilago avenae*, while the upper have the appearance of *Ustilago levis*. The two species, however, can be separated by microscopic observation of the spores. The spores of *Ustilago levis* are smooth while those of *Ustilago avenae* are minutely echinulate. The spores of both species are about the same size and shape and are lighter colored on one side.

Apparently these two smuts are confined to the genus *Avena*. A smut very similar to *Ustilago levis* attacks *Arrhenatherum elatius* but it is recognized as a distinct species, partly because of its perennial mycelium.

In the older literature these two species have not been distinguished. Kellerman and Swingle¹⁸ first recognized the differences between them and described the smooth spored variety. Later Magnus²² gave this form specific rank.

Magnus²² records in the Mark Brandenburg, Germany, *Ustilago avenae* on *Avena sativa*, *Avena sterilis*, *Avena tartarica* and *Avena tartarica* var. *nigra*; *Ustilago levis* is listed on *Avena sativa* and *Avena nuda*. Lindau²¹ later, for the same locality, lists *Ustilago avenae* on *Avena orientalis*, *Avena sativa*, *Avena sterilis*, *Avena strigosa*, *Avena tartarica* and a hybrid form; *Ustilago levis* is recorded on *Avena nuda* and *Avena sativa*. Clinton⁴ in the United States lists *Ustilago avenae* on *Avena sativa* and *Avena fatua*, the smut on the latter host being

recorded only from California; *Ustilago levis* is listed on *Avena sativa*. This species probably is used to include various cultivated varieties which are regarded as belonging to such species as *Avena sativa orientalis* and *Avena sterilis*.

McAlpine²⁷ reports *Ustilago avenae* on wild oats in Australia. He used spores from wild oats successfully to infect both wild and cultivated oats. He also infected wild oats with spores from cultivated oats. He²⁸ does not report the occurrence of *Ustilago levis*.

Schellenberg²⁸ records *Ustilago avenae* on *Avena sativa*, *Avena orientalis* and *Avena fatua* in Switzerland; *Ustilago levis* is reported on *Avena sativa*.

Lind²⁹, in Denmark, records *Ustilago avenae* on *Avena sativa*, *Avena orientalis*, *Avena fatua* and *Avena fatua* X *Avena sativa*; *Ustilago levis* is listed on *Avena sativa*, *Avena orientalis*, *Avena strigosa* and *Avena strigosa* X *Avena patula*.

Many observations have been recorded indicating the occurrence of oat smut in different varieties. Arthur¹, in New York, notes slight variations in the amount of smut in three different varieties—American Triumph, ten per cent; Board of Trade, eight and five-tenths per cent; New Australian seven to fifteen per cent in different plots. Variable amounts of smut occurred among thirty other varieties. Plumb²⁹ records from one to three per cent in Race Horse, even when smutted kernels are planted in the soil beside sound grains, as compared with more than nine per cent in White Australian.

Jensen¹², in Denmark, observed the amount of smut in twenty-two varieties during the years 1885, 1886, and 1887. During 1885, the highest per cent recorded was twenty-eight and several varieties were free from smut. In 1886, the highest per cent was forty-five and all varieties were infected to a greater or less extent. In 1887, the highest per cent was seventy-five and again all varieties were infected. The variety Blainsly in general showed the greatest amount of smut. No special efforts were made to inoculate the seed but it is clear that in successive years there was greater contamination of the different varieties. Since there was no inoculation there was no good test for comparative susceptibility. It may be noted, however, that *Avena strigosa*, grown these same years, remained entirely free from smut.

Hickman⁹¹⁰, in Ohio, notes the prevalence of smut in a number of varieties of oats. His most extensive report, published in 1895, indicates the amount of smut in sixty-five varieties. Most of these were infected between one and ten per cent; several, however, gave higher percentages. None proved free. Hickman, further, notes the

increase of smut in varieties in successive years due to greater contamination of the seed. Selby³⁶ has also recorded the occurrence of smut in oat varieties. In 1895, he records the amount in twenty-seven varieties which generally showed high percentages of infection. Various agricultural experiment stations, in bulletins or reports, make more or less casual reference to the prevalence of smut in different varieties of oats.

Zavitz⁴¹⁴³, in a series of reports, notes the marked freedom of Early Ripe oats from smut. In 1906 Early Ripe, Joannette, Siberian, American Banner and Black Tartarian were free from smut as a result of seed treatment. These varieties were then grown from 1907 to 1914 without any further seed treatment. No efforts were made to inoculate the seed. Further, any smutted plants that appeared in the plots were removed before harvest, thus lessening the chances of inoculation. During these years there was a very marked increase in the amount of smut in Black Tartarian and small amounts in Joannette, Siberian and American Banner. In Early Ripe only one smutted head was found in 1913 and two in 1914.

Rose³² used sixty-three varieties, planting two sets of seed, one early and the other late in the season. Both sets were carefully inoculated with smut spores. Great differences were noted in the amount of smut in the different varieties. Two varieties, "Schwarzer Brie" and "Oberbrucher," gave negative results. The other varieties gave percentages of infection varying from one and seventy-six hundredths to seventeen and seventy-seven hundredths. In general a higher percentage of infection was obtained in the later planting.

Since 1914, the writer has carried out experiments bearing upon the question of varietal susceptibility and resistance of oats to the loose and covered smuts. In general the dry seed of the oat varieties used were inoculated and then planted in plots as early in the spring as oat plantings could be made. In practically every case one or more rod rows of each variety were planted. The seeding was at a low rate which permitted abundant stooling of the plants. Between fifty and one hundred plants usually matured in the row.

In some of the work the seed was treated, before inoculation, by dipping for about ten minutes in a solution of formaldehyde (one to three hundred and twenty) and covering for a few hours. To a great extent this was not necessary as the seed was collected from clean plots and handled in such a way as to avoid contamination. Occasionally, however, some smut occurred in the check rows which were planted each season, unless the seed had been treated.

Germination tests of the spores used for inoculation were always

made and only those collections which showed a very high rate of germination were used. As stated before, the dry seed was thoroly mixed with a quantity of dry spores. In some cases the seed was first soaked for three to five hours before being inoculated. Immediately after inoculation with the dry spores such pre-soaked seed was planted.

Both loose and covered smut were used each season except that no experiments were carried out with *Ustilago avenae* in 1915 and none with *Ustilago levis* in 1914 and 1917. Separate samples of seed of the varieties were inoculated with the spores of each species of smut and planted in adjacent plots. It was not entirely possible, however, to avoid some mixing of the two smuts during inoculation, planting, etc. In the main, however, each plot contained only the smut whose spores were sown on the seed.

The results obtained during the past six years with loose and covered smuts are summarized in Tables 3 and 4. The tables record the name of the species and variety, the seed identification number, the total number of plants produced and the per cent of plants infected with smut.

Generally a record was kept with reference to the percentage of smutted heads as well as the percentage of smutted plants. The tables, however, are all based on the latter, as plant infection is regarded as the most significant in this connection. As a matter of fact, in practically every case, the percentage of smutted heads was always less than that of the plants, due largely to the fact that smutted plants frequently produced some sound heads. On this account the percentage of smutted heads doubtless represents a more accurate method for determining the loss due to smut.

TABLE 3.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Avenae* (Pers.) JENS.

Species and Variety	Seed No.	1914		1916		1917		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
<i>Avena brevis</i> Roth.	1	105	0	98	0	64	0	11	0	176	0
<i>Avena brevis</i> Roth.	77	.....	.....	104	0	89	0	121	0	127	0
<i>Avena brevis</i> Roth.	134	.....	.....	.....	.....	.....	.....	100	0	.....	.....
<i>Avena fatua</i> L.	78	.....	.....	11	27.3	.....	.....	8	0	50	38.0
<i>Avena fatua</i> L.	143	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Avena fatua</i> L.—	79	.....	.....	27	26.9	.....	.....	.....	.....	.....	.....
var. <i>glabrata</i>	25	.....	.....	145	85.0	158	98.1	53	81.1	.....	.....
<i>Avena nuda</i> L.	144	.....	.....	123	34.1	125	85.6	94	53.1	103	49.5
<i>Avena nuda</i> L.	30	19	47.3	192	86.4	32	68.7	100	100.	144	94.4
var. <i>chinensis</i>	26	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
var. <i>elegantissima</i>	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Avena sativa</i> L.—	.....	425	41.8	.....	.....	93	23.6	105	12.3	.....	.....
var. <i>Achotatt</i>	82	.....	.....	.....	.....	.....	.....	105	12.3	.....	.....
var. <i>American Banner</i>	35	.....	.....	115	9.5	.....	.....	115	6.9	47	8.5
var. <i>aristata</i>	7	.....	.....	115	8.7	.....	.....	69	5.7	22	0.
var. <i>aurea</i>	114	.....	.....	.....	.....	.....	.....	73	39.7	30	20.0
var. <i>Awnless Probesteier</i>	115	.....	.....	.....	.....	.....	.....	90	16.6	18	22.2
var. <i>Belyak</i>	83	.....	.....	.....	.....	.....	.....	115	40.8	25	32.0
var. <i>Big Four</i>	116	.....	.....	.....	.....	.....	.....	86	3.4	253	0.
var. <i>Black Diamond</i>	117	.....	.....	.....	.....	.....	.....	98	0.	37	10.8
var. <i>Black Mesdag</i>	118	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
var. <i>Black Norway</i>	84	499	10.8	.....	.....	.....	.....	.....	.....	.....	.....
var. <i>Black Orr</i>	8	.....	.....	122	13.1	142	9.8	95	21.0	74	25.6
var. <i>brunnea</i>	119	.....	.....	.....	.....	.....	.....	104	37.5	49	47.0
var. <i>Canadian</i>	145	.....	.....	.....	.....	.....	.....	.....	.....	49	30.6
var. <i>C. I. 602</i>	146	.....	.....	.....	.....	.....	.....	.....	.....	50	30.0
var. <i>C. I. 603</i>	127	.....	.....	.....	.....	.....	.....	75	4.0	53	1.8
var. <i>C. I. 606</i>	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE 3.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Avenae* (Pers.) Jens. (Continued)

Species and Variety	Seed No.	1914		1916		1917		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
<i>Avena sativa</i> L.—	147	.....	.....	.....	.....	.....	.....	.....	.....	44	20.4
var. C. I. 606	148	.....	.....	.....	.....	.....	.....	.....	.....	19	5.2
var. C. I. 620	120	.....	.....	.....	.....	.....	.....	.....	.....	49	6.1
var. Culberson	192	.....	.....	.....	.....	.....	.....	.....	.....	235	10.6
var. Culberson	87	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
var. Currell No. 6	85	427	51.2	.....	.....	.....	.....	.....	.....	.....	.....
var. Czar of Russia	149	.....	.....	.....	.....	.....	.....	.....	.....	43	37.2
var. Danish Island .....	.....	542	72.8	77	9.0	.....	.....	.....	.....	.....	.....
var. Early Champion	150	.....	.....	.....	.....	.....	.....	.....	.....	62	38.7
var. Early Champion	197	.....	.....	.....	.....	.....	.....	.....	.....	272	41.5
var. Early Dakota	151	.....	.....	.....	.....	.....	.....	.....	.....	58	29.3
var. Early Gothland	152	.....	.....	.....	.....	.....	.....	.....	.....	31	67.7
var. Early Gothland	86	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
var. Early Illinois	153	.....	.....	.....	.....	.....	.....	.....	.....	30	60.0
var. Garton	154	.....	.....	.....	.....	.....	.....	.....	.....	52	21.1
var. Golden Drop	89	435	51.0	.....	.....	133	18.7	.....	.....	.....	.....
var. Great Dakota	90	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
var. Green Russian	121	.....	.....	.....	.....	.....	.....	.....	.....	97	13.9
var. Green Russian	41	.....	.....	54	22.2	.....	.....	.....	.....	.....	.....
var. <i>grisea</i>	91	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
var. Iowa 103	92	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
var. Iowa 105	155	.....	.....	.....	.....	.....	.....	.....	.....	45	22.2
var. Irish Victor	93	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
var. Japan 144	156	.....	.....	.....	.....	.....	.....	.....	.....	57	57.8
var. Japan Selection	125	.....	.....	.....	.....	.....	.....	.....	.....	60	10.0
var. Joannette	157	.....	.....	.....	.....	.....	.....	.....	.....	35	60.0
var. June	94	.....	.....	.....	.....	80	17.5	.....	.....	.....	.....
var. Kherson .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE 3.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Avenae* (PERS.) JENS. (Continued)

Species and Variety	Seed No.	1914		1916		1917		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
<i>Avena sativa</i> L.—											
var. Kherson	158	....	....	....	....	....	....	....	....	49	42.8
var. Kherson Selection	159	....	....	....	....	....	....	....	....	54	44.4
var. <i>krusei</i>	9	....	....	100	0	25	12.0	37	2.7	12	0
var. Lincoln	95	457	47.0	....	....	116	5.1	108	25.9	....	....
var. Lincoln	160	....	....	....	....	....	....	....	....	48	35.4
var. Minnesota No. 270...	....	352	39.5	....	....	....	....	....	....	....	....
var. Monarch .....	....	795	40.8	....	....	....	....	....	....	....	....
var. Monarch	161	....	....	....	....	....	....	....	....	....	....
var. Monarch Selection	162	....	....	....	....	....	....	....	....	57	0
var. <i>montana</i>	10	....	....	127	5.5	91	3.2	99	10.1	22	54.5
var. <i>mutica</i>	11	....	....	114	14.9	....	....	84	11.9	22	4.5
var. <i>mutica</i>	42	....	....	76	38.1	....	....	68	45.5	....	....
var. <i>mutica</i>	43	....	....	168	13.1	137	14.5	104	46.1	63	14.2
var. <i>mutica</i>	45	....	....	112	3.5	126	0	100	1.0	55	20.0
var. <i>mutica</i>	46	....	....	....	....	....	....	110	19.0	49	4.0
var. <i>mutica</i>	47	....	....	....	....	....	....	115	43.4	24	12.5
var. <i>mutica</i>	48	....	....	128	18.7	....	....	121	33.8	51	21.5
var. <i>mutica</i>	49	....	....	....	....	....	....	92	22.8	54	29.6
var. <i>mutica</i>	50	....	....	....	....	....	....	117	23.0	3	33.3
var. <i>mutica</i>	51	....	....	102	13.7	....	....	108	29.6	....	....
var. <i>mutica</i>	52	....	....	88	2.2	....	....	106	54.7	65	6.1
var. <i>mutica</i>	53	....	....	....	....	....	....	93	41.9	34	5.8
var. <i>mutica</i>	54	....	....	157	26.5	....	....	60	36.6	16	43.7
var. <i>mutica</i>	55	....	....	....	....	....	....	86	26.7	3	0
var. <i>mutica</i>	56	....	....	....	....	....	....	109	33.0	2	50.0
var. <i>mutica</i>	57	....	....	....	....	....	....	118	15.2	....	....
var. <i>mutica</i>	58	....	....	....	....	....	....	105	20.0	53	3.7
var. <i>mutica</i> .....	....	....	....	....	....	....	....	....	....	52	7.7

TABLE 3.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Avenae* (PERS.) JENS. (Continued)

Species and Variety	Seed No.	1914		1916		1917		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
<i>Avena sativa</i> L.—	96	457	30.4	.....	.....	.....	.....	75	17.3	.....	.....
var. National	97	.....	.....	.....	.....	.....	.....	96	37.5	.....	.....
var. Nichol's Black Comet	12	.....	.....	97	9.3	11	0.	51	45.1	16	37.5
var. <i>nigra</i>	56	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
var. <i>nigra</i>	59	.....	.....	60	3.3	.....	.....	100	10.0	15	13.3
var. <i>nigra</i>	60	.....	.....	68	8.8	.....	.....	.....	.....	.....	.....
var. <i>nigra</i>	70	.....	.....	65	0.	.....	.....	100	0.	290	0.
var. North Finnish	123	.....	.....	.....	.....	.....	.....	108	38.8	96	6.2
var. Old Island Black	163	.....	.....	.....	.....	.....	.....	.....	.....	56	8.9
var. <i>praegravis</i>	13	.....	.....	.....	.....	.....	.....	77	46.7	.....	.....
var. <i>praegravis</i>	61	.....	.....	.....	.....	.....	.....	103	25.2	29	34.4
var. <i>praegravis</i>	62	.....	.....	.....	.....	.....	.....	121	23.9	22	36.3
var. Scottish Chief	124	.....	.....	.....	.....	.....	.....	77	14.2	47	17.0
var. Sensation	99	.....	.....	.....	.....	.....	.....	95	23.1	.....	.....
var. Siberian	100	.....	.....	.....	.....	.....	.....	54	31.4	.....	.....
var. Silvermine	101	338	49.1	.....	.....	133	14.2	67	43.2	.....	.....
var. Silvermine	164	.....	.....	.....	.....	.....	.....	.....	.....	36	16.6
var. Silvermine Selection	165	.....	.....	.....	.....	.....	.....	.....	.....	41	22.0
var. Sixty-Day	166	.....	.....	.....	.....	.....	.....	.....	.....	59	35.5
var. Sixty-Day Selection	167	.....	.....	.....	.....	.....	.....	.....	.....	60	8.3
var. Swedish Select	168	.....	.....	.....	.....	.....	.....	.....	.....	27	29.6
var. Tobolsk	122	.....	.....	.....	.....	.....	.....	.....	.....	59	18.6
var. <i>trisperma</i>	64	.....	.....	73	16.4	.....	.....	100	4.0	8	12.5
var. Victor	126	.....	.....	.....	.....	.....	.....	85	5.8	.....	.....
var. White Queen	103	.....	.....	.....	.....	137	17.5	82	47.5	28	46.4
var. White Russian	104	.....	.....	.....	.....	.....	.....	68	51.4	.....	.....
var. White Schoenen	105	1138	25.3	.....	.....	.....	.....	86	39.5	.....	.....

TABLE 3.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Avenae* (Pers.) Jens (Continued)

Species and Variety	Seed No.	1914		1916		1917		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
<i>Avena sativa</i> L.—	107	438	35.6	.....	.....	118	7.6	103	24.2	.....	.....
var. Wide Awake	.....	389	31.6	.....	.....	.....	.....	.....	.....	.....	.....
var. Wisconsin Wonder	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Avena sativa orientalis</i> L.—	108	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
var. Black Tartarian	31	.....	.....	71	15.5	.....	.....	96	5.2	59	20.3
var. <i>flava</i>	170	.....	.....	.....	.....	.....	.....	93	17.2	38	15.8
var. Garton 585	109	.....	.....	.....	.....	.....	.....	.....	.....	18	11.0
var. Garton 748	171	.....	.....	.....	.....	.....	.....	114	30.7	65	18.4
var. Garton	88	477	44.2	.....	.....	.....	.....	100	56.0	21	33.3
var. Garton's Black	172	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
var. Garton Gray	173	.....	.....	.....	.....	.....	.....	.....	.....	29	38.0
var. Golden Giant	110	.....	.....	.....	.....	.....	.....	98	40.8	50	16.0
var. Green Mountain	32	.....	.....	92	9.8	.....	.....	94	36.1	38	47.3
var. <i>mutica</i>	4	34	52.9	.....	.....	.....	.....	.....	.....	57	21.0
var. <i>obtusata</i>	33	.....	.....	82	4.8	140	6.4	118	14.4	.....	.....
var. <i>obtusata</i>	65	16	25.0	126	37.3	104	9.6	85	15.2	5	17.5
var. <i>pugnax</i>	66	30	36.6	.....	.....	.....	.....	.....	.....	.....	60.0
var. <i>pugnax</i>	14	.....	.....	141	16.3	.....	.....	86	10.4	15	0.
var. <i>setosa</i>	111	.....	.....	.....	.....	.....	.....	90	14.4	48	25.0
var. Sparrowbill	102	.....	.....	.....	.....	.....	.....	100	43.0	.....	.....
var. Sparrowbill	112	.....	.....	.....	.....	.....	.....	84	11.9	36	27.7
var. Storm King	5	.....	.....	122	13.9	118	22.0	82	20.7	.....	.....
var. <i>tartarica</i>	34	.....	.....	133	17.3	.....	.....	.....	.....	.....	.....
var. <i>tartarica</i>	113	.....	.....	.....	.....	.....	.....	79	11.3	46	17.3
var. Tartar King	40	4	0.	136	2.9	.....	.....	105	17.0	24	41.6
var. <i>tristis</i>	106	262	22.9	.....	.....	.....	.....	63	28.5	.....	.....
var. White Tartar	174	.....	.....	.....	.....	.....	.....	.....	.....	38	34.2
var. White Tartar	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE 3.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Avenae* (PERS.) JENS. (Continued)

Species and Variety	Seed No.	1914		1916		1917		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
<i>Avena sterilis</i> L.	27	18	5.5	89	11.2	....	....	18	38.8	....	....
<i>Avena sterilis</i> L.	28	12	0.	130	0.	....	....	54	5.5	5	0.
<i>Avena sterilis</i> L.—											
var. Burt	67	359	2.5	215	0.	156	0.	68	4.4	83	1.2
var. Burt ¹	74	412	30.0	63	4.7	....	....	94	18.0	111	6.3
var. Burt	175	....	....	....	....	....	....	....	....	31	0.
var. Burt	253	....	....	....	....	....	....	....	....	142	3.6
var. Early Ripe ²	75	377	8.4	113	2.6	20	0.	100	5.0	142	6.2
var. Fulghum	129	....	....	....	....	....	....	100	0.	205	0.
var. Fulghum	257	....	....	....	....	....	....	100	....	194	1.9
var. Italian Rustproof	260	....	....	....	....	....	....	....	....	60	3.3
var. <i>ladoviciana</i>	80	....	....	102	4.9	103	9.7	91	3.3	....	....
var. <i>ladoviciana</i>	176	....	....	....	....	....	....	....	....	29	0.
var. <i>nigra</i>	130	....	....	....	....	....	....	....	....	26	0.
var. Red Rustproof	98	....	....	....	....	125	10.4	76	32.8	....	....
var. Red Rustproof	131	....	....	....	....	....	....	....	....	19	10.5
var. Selection	132	....	....	....	....	....	....	90	4.4	50	4.0
var. Turkish Rustproof	267	....	....	....	....	....	....	....	....	50	0.
var. Turkish Rustproof	268	....	....	....	....	....	....	....	....	48	0.
var. Turkish Rustproof	269	....	....	....	....	....	....	....	....	254	0.
<i>Avena strigosa</i> Schreb.	29	25	0.	105	0.	81	0.	100	0.	173	0.
<i>Avena strigosa</i> Schreb. ³	76	....	....	118	0.	76	0.	100	0.	115	0.
<i>Avena strigosa</i> Schreb.	133	....	....	....	....	....	....	100	0.	....	....

¹This variety does not resemble very closely the other Burt strains.²This variety resembles very closely Burt (74).³This strain was received under the name of *Avena barbata*.

TABLE 4.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Levis* (K. & S.) MAGN.

Species and Variety	Seed No.	1915		1916		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
<i>Avena brevis</i> Roth.	1	275	0.	130	0.	100	0.	127	0.
<i>Avena brevis</i> Roth.	77	.....	.....	120	0.	100	0.	144	0.
<i>Avena brevis</i> Roth.	134	.....	.....	.....	.....	100	0.	.....	.....
<i>Avena fatua</i> L.	78	.....	.....	23	17.4	3	.....	51	60.7
<i>Avena fatua</i> L.	143	.....	.....	.....	.....	.....	.....	.....	.....
<i>Avena fatua</i> L.—	.....	.....	.....	.....	.....	.....	.....	.....	.....
var. <i>glabrata</i>	79	.....	.....	20	40.	80	97.5	.....	.....
<i>Avena nuda</i> L.	25	.....	.....	.....	.....	.....	.....	.....	.....
<i>Avena nuda</i> L.	144	.....	.....	.....	.....	.....	.....	99	65.6
<i>Avena nuda</i> L.—	.....	.....	.....	.....	.....	.....	.....	108	92.5
var. <i>chinensis</i>	30	.....	.....	.....	.....	75	8.0	.....	.....
var. <i>elegantissima</i>	26	42	73.8	.....	.....	80	22.5	.....	.....
<i>Avena sativa</i> L.—	.....	.....	.....	.....	.....	.....	.....	.....	.....
var. American Banner	82	.....	.....	.....	.....	85	56.4	.....	.....
var. <i>aristata</i>	35	.....	.....	101	5.9	108	19.4	45	13.3
var. <i>aurca</i>	7	98	3.0	94	19.1	.....	.....	12	0.
var. Awnless Probsteier	114	.....	.....	.....	.....	74	18.9	27	11.1
var. Belyak	115	.....	.....	.....	.....	79	10.1	21	28.5
var. Big Four	83	.....	.....	.....	.....	92	42.3	.....	.....
var. Black Diamond	116	.....	.....	.....	.....	90	2.2	24	8.3
var. Black Mesdag	117	.....	.....	.....	.....	93	0.	289	0.
var. Black Norway	118	.....	.....	.....	.....	.....	.....	37	0.
var. Black Orr	84	.....	.....	.....	.....	.....	.....	.....	.....
var. <i>brunnea</i>	8	58	5.1	117	31.6	95	10.5	66	4.5
var. Canadian	119	.....	.....	.....	.....	81	18.5	45	53.3
var. C. I. 602	145	.....	.....	.....	.....	95	81.0	40	0.
var. C. I. 603	146	.....	.....	.....	.....	.....	.....	50	54.0
var. C. I. 606	127	.....	.....	.....	.....	75	2.6	53	18.8

TABLE 4.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Levis* (K. & S.) MAGN. (Continued)

Species and Variety	Seed No.	1915		1916		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
<i>Avena sativa</i> L.—	147	.....	.....	.....	.....	.....	.....	56	33.9
var. C. I. 606	148	.....	.....	.....	.....	.....	.....	13	53.8
var. C. I. 620	120	.....	.....	.....	.....	85	23.5	54	14.8
var. Culberson	192	.....	.....	.....	.....	.....	.....	262	12.2
var. Culberson	87	.....	.....	.....	.....	86	10.4	.....	.....
var. Currell No. 6	85	.....	.....	.....	.....	84	46.4	.....	.....
var. Czar of Russia	149	.....	.....	.....	.....	.....	.....	45	15.5
var. Danish Island .....	.....	.....	.....	.....	.....	.....	.....	.....	.....
var. Early Champion .....	.....	758	36.0	104	10.5	.....	.....	.....	.....
var. Early Champion	150	.....	.....	.....	.....	.....	.....	.....	82.3
var. Early Champion	197	.....	.....	.....	.....	.....	.....	266	42.8
var. Early Dakota	151	.....	.....	.....	.....	.....	.....	55	38.1
var. Early Gothland	152	.....	.....	.....	.....	.....	.....	45	2.2
var. Early Illinois	86	.....	.....	.....	.....	100	29.0	.....	.....
var. Garton	153	.....	.....	.....	.....	.....	.....	25	28.0
var. Golden Drop	154	.....	.....	.....	.....	.....	.....	48	50.0
var. Great Dakota	89	.....	.....	.....	.....	107	13.0	.....	.....
var. Green Russian	90	.....	.....	.....	.....	99	10.1	.....	.....
var. Green Russian	121	.....	.....	.....	.....	99	17.1	96	20.8
var. <i>grisea</i>	41	.....	.....	.....	.....	110	20.0	.....	.....
var. Iowa 103	91	.....	.....	.....	.....	80	43.7	.....	.....
var. Iowa 105	92	.....	.....	.....	.....	82	29.2	.....	.....
var. Irish Victor	155	.....	.....	.....	.....	.....	.....	48	45.8
var. Japan 144	93	.....	.....	.....	.....	95	14.7	.....	.....
var. Japan Selection	156	.....	.....	.....	.....	.....	.....	79	67.0
var. Joannette	125	.....	.....	.....	.....	67	19.4	65	15.5
var. June	157	.....	.....	.....	.....	.....	.....	46	58.7
var. Kherson	94	256	23.0	.....	.....	75	32.0	.....	.....

TABLE 4.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Levis* (K. & S.) MAGN. (Continued)

Species and Variety	Seed No.	1915		1916		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
<i>Avena sativa</i> L.—	158	.....	.....	.....	.....	.....	.....	25	46.1..
var. Kherson	159	.....	.....	.....	.....	.....	.....	59	69.4
var. Kherson Selection	9	120	0.	136	19.1	40	40.0	8	37.5
var. <i>kranset</i>	95	.....	.....	.....	.....	92	23.9	.....	.....
var. Lincoln	160	.....	.....	.....	.....	.....	.....	40	45.0
var. Lincoln	161	.....	.....	.....	.....	.....	.....	44	61.3
var. Monarch	162	.....	.....	.....	.....	.....	.....	26	0.
var. Monarch Selection	10	144	2.0	104	1.9	69	21.7	18	16.6
var. <i>montana</i>	11	.....	.....	80	0.	.....	.....	.....	.....
var. <i>mutica</i>	42	84	4.7	95	17.9	59	13.5	39	0.
var. <i>mutica</i>	43	.....	.....	104	5.7	91	25.2	45	11.1
var. <i>mutica</i>	45	.....	.....	84	0.	100	2.0	47	0.
var. <i>mutica</i>	46	.....	.....	.....	.....	100	1.0	32	3.1
var. <i>mutica</i>	47	.....	.....	.....	.....	99	26.2	58	1.7
var. <i>mutica</i>	48	.....	.....	98	14.3	87	27.5	52	11.5
var. <i>mutica</i>	49	.....	.....	.....	.....	80	25.0	5	0.
var. <i>mutica</i>	50	.....	.....	.....	.....	91	12.0	.....	.....
var. <i>mutica</i>	51	.....	.....	86	16.3	82	32.9	57	1.7
var. <i>mutica</i>	52	.....	.....	73	6.8	86	23.2	37	2.7
var. <i>mutica</i>	53	.....	.....	.....	.....	108	23.1	6	16.6
var. <i>mutica</i>	54	.....	.....	.....	.....	75	36.0	3	33.3
var. <i>mutica</i>	55	.....	.....	.....	.....	81	22.2	3	33.3
var. <i>mutica</i>	56	.....	.....	.....	.....	85	34.1	18	22.2
var. <i>mutica</i>	57	.....	.....	.....	.....	72	16.6	54	0.
var. <i>mutica</i>	58	.....	.....	.....	.....	100	48.0	46	2.1
var. National	96	.....	.....	.....	.....	93	16.1	.....	.....
var. Nichol's Black Comet	97	221	21.7	.....	.....	90	37.7	.....	.....

TABLE 4.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Levis* (K. & S.) MAGN. (Continued)

Species and Variety	Seed No.	1915		1916		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
<i>Avena sativa</i> L.—									
var. <i>nigra</i>	12	120	0.	89	3.3	26	15.3	19	0.
var. <i>nigra</i>	59	.....	.....	115	0.	122	0.	324	0.
var. <i>nigra</i>	70	.....	.....	.....	.....	100	0.	81	34.5
var. North Finnish	123	.....	.....	.....	.....	71	29.5	69	24.0
var. Old Island Black	163	.....	.....	.....	.....	.....	.....	.....	.....
var. <i>praegravis</i>	13	.....	.....	.....	.....	71	50.7	.....	.....
var. <i>praegravis</i>	61	.....	.....	.....	.....	98	27.5	39	30.7
var. <i>praegravis</i>	62	102	7.8	.....	.....	117	28.2	25	8.0
var. Scottish Chief	124	.....	.....	.....	.....	59	10.1	47	0.
var. Sensation	99	.....	.....	.....	.....	83	22.8	.....	.....
var. Siberian	100	.....	.....	.....	.....	81	27.1	.....	.....
var. Silvermine	101	166	9.0	.....	.....	59	22.0	.....	.....
var. Silvermine	164	.....	.....	.....	.....	.....	.....	31	35.4
var. Silvermine	165	.....	.....	.....	.....	.....	.....	59	35.5
var. Silvermine Selection	166	.....	.....	.....	.....	.....	.....	46	54.3
var. Sixty-Day Selection	167	.....	.....	.....	.....	.....	.....	47	29.7
var. Swedish Select	168	.....	.....	.....	.....	.....	.....	31	45.1
var. Tobolsk	122	.....	.....	.....	.....	120	37.5	82	41.4
var. <i>trisperma</i>	64	120	0.	80	5.0	85	21.1	8	0.
var. Victor	126	.....	.....	.....	.....	66	21.2	24	66.6
var. White Queen	103	.....	.....	.....	.....	100	3.0	.....	.....
var. White Russian	104	.....	.....	.....	.....	111	31.5	.....	.....
var. White Schoenen	105	.....	.....	.....	.....	90	12.2	.....	.....
var. Wide Awake	107	.....	.....	.....	.....	71	38.0	.....	.....
<i>Avena sativa orientalis</i> L.—									
var. Black Tartarian	108	.....	.....	114	17.6	94	41.4	47	12.7
var. <i>flava</i>	31	.....	.....	.....	.....	.....	.....	26	23.0

TABLE 4.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Levis* (K. & S.) MAGN. (Continued)

Species and Variety	Seed No.	1915		1916		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
<i>Avena sativa orientalis</i> L.—									
var. Garton's Black	88	....	....	....	....	87	4.6	....	....
var. Garton 585	170	....	....	....	....	....	....	18	44.4
var. Garton 748	109	....	....	....	....	100	49.0	60	15.0
var. Garton	171	....	....	....	....	....	....	18	22.2
var. Garton Gray	172	....	....	....	....	....	....	20	70.0
var. Golden Giant	173	....	....	....	....	....	....	46	45.6
var. Green Mountain	110	....	....	....	....	100	43.0	31	25.8
var. <i>mutica</i>	32	....	....	....	....	134	11.9	70	18.5
var. <i>obtusata</i>	33	128	7.0	99	11.0	88	14.7	41	9.0
var. <i>pagnar</i>	65	....	....	126	26.2	50	2.0	8	12.5
var. <i>setosa</i>	14	127	7.0	97	7.2	86	18.6	14	0.
var. Sparrowbill	102	....	....	....	....	102	23.5	....	....
var. Sparrowbill	111	....	....	....	....	113	28.3	55	14.5
var. Storm King	112	....	....	....	....	86	6.9	33	15.1
var. <i>tarlarica</i>	5	151	6.6	104	6.7	89	19.1	....	....
var. <i>tarlarica</i>	34	....	....	171	20.4	....	....	....	....
var. Tartar King	113	....	....	....	....	80	22.5	60	16.6
var. <i>tristis</i>	40	129	19.3	154	16.9	40	42.5	17	0.
var. White Tartar	106	....	....	....	....	80	35.0	....	....
var. White Tartar	174	....	....	....	....	....	....	41	9.7
<i>Avena sterilis</i> L.	27	116	22.4	132	0.	22	50.0	....	....
<i>Avena sterilis</i> L.	28	....	....	122	0.	56	0.	7	0.
<i>Avena sterilis</i> L.—									
var. Burt	67	179	1.6	206	0.	70	0.	87	0.
var. Burt ¹	74	....	....	90	0.	100	14.0	121	6.6
var. Burt	175	....	....	....	....	....	....	36	0.
var. Burt	253	....	....	....	....	....	....	202	1.9

TABLE 4.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Levis* (K. & S.) MAGN. (Continued)

Species and Variety	Seed No.	1915		1916		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
<i>Avena sterilis</i> L.	75	124	2.4	105	0.	70	7.1	148	6.0
var. Early Ripe ²	129	.....	.....	.....	.....	69	1.4	204	0.4
var. Fulghum	257	.....	.....	.....	.....	.....	.....	218	1.3
var. Italian Rustproof	260	.....	.....	.....	.....	.....	.....	65	4.6
var. <i>ludoviciana</i>	80	.....	.....	97	9.3	96	20.8	.....	.....
var. <i>ludoviciana</i>	176	.....	.....	.....	.....	.....	.....	23	0.
var. <i>nigra</i>	130	.....	.....	.....	.....	.....	.....	37	0.
var. Red Rustproof	98	226	26.1	.....	.....	78	56.4	.....	.....
var. Red Rustproof	131	.....	.....	.....	.....	120	6.6	.....	.....
var. Selection	132	.....	.....	.....	.....	.....	.....	54	0.
var. Turkish Rustproof	267	.....	.....	.....	.....	.....	.....	50	4.0
var. Turkish Rustproof	268	.....	.....	.....	.....	.....	.....	.....	.....
<i>Avena strigosa</i> Schreb.	29	60	0.	117	0.	100	0.	260	0.
<i>Avena strigosa</i> Schreb. ³	76	.....	.....	.....	.....	100	0.	168	0.
<i>Avena strigosa</i> Schreb.	133	.....	.....	.....	.....	100	0.	105	0.

¹This variety does not resemble very closely the other Burt strains.²This variety resembles very closely Burt (74).³This strain was received under the name of *Avena barbata*.

Results for 1914.—In one experiment eleven varieties belonging to seven species of *Avena* were inoculated, after pre-soaking the seed for four to five hours, with the dry spores of *Ustilago avenae*. The seed was planted very late, May 1. The number of plants that developed in some varieties was very small and, in consequence, the results are not at all conclusive. However, three varieties of *Avena sativa orientalis* L., one variety of *Avena nuda* L. and Early Champion, a variety of *Avena sativa* L., gave relatively high percentages of infection. One strain of Burt and Early Ripe, varieties of *Avena sterilis* L., proved free from smut. Further, no infection occurred with *Avena brevis* Roth. and *Avena strigosa* Schreb.

In a second experiment eighteen varieties of commonly cultivated oats were tested. Most of these belonged to *Avena sativa* L. and a few to *Avena sativa orientalis* L.; Early Ripe and Burt, varieties of *Avena sterilis* L., were included. The dry seed was inoculated with the dry spores.

Infection occurred in every variety; it amounted to 2.5 per cent in Burt (67), and 7.5 per cent in Early Ripe (75). In practically all the other varieties the percentage of infection was from about twenty to more than sixty per cent.

Results for 1915.—In this year only *Ustilago levis* was used. The dry seed of twenty-three varieties were inoculated with the dry spores. In nearly every case the seed was divided into two lots, one of which was planted April 2 and the other April 24. In the general table the combined results of these two plantings are given. *Avena brevis* Roth., *Avena strigosa* Schreb. and a few varieties of *Avena sativa* L. gave negative results. A number of other varieties including Burt and Early Ripe were only slightly infected. *Avena sativa* L. var. *Early Champion* and *Avena nuda* L. var. *elegantissima* gave relatively high percentages of infection.

Results for 1916.—Forty-three strains or varieties belonging to nine species were inoculated with the spores of *Ustilago avenae*; thirty-five of these were also inoculated with the spores of *Ustilago levis*. Several gave negative results with both smuts, namely, *Avena brevis* Roth. (two strains), *Avena sativa* L. var. *nigra* (70), *Avena sterilis* L. (28), *Avena sterilis* L. var. *Burt* (67) and *Avena strigosa* Schreb. A few others were infected by one smut but not by the other. Varieties of *Avena nuda* L. were severely infected with *Ustilago avenae* but were not tested with *Ustilago levis*. In the other varieties the percentages of infection varied greatly, some more severely with the loose smut, others more severely with the covered smut.

Results for 1917.—During this season only *Ustilago avenae*

was used in the experiments. Seed of twenty-seven strains and varieties were inoculated with the dry spores. One set of seed was planted March 24 and a second set on April 12. In the general table the results for both planting dates are combined.

No infection occurred in *Avena brevis* Roth., *Avena sativa* L. var. *mutica* (45) and *nigra* (12), *Avena sterilis* L. var. *Burt* (67) and *Early Ripe* (75), nor *Avena strigosa* Schreb. The varieties of *Avena nuda* L. gave very high infection percentages—68.7 to 98.1.

Results for 1918.—Ninety-nine strains and varieties belonging to eight species were inoculated with spores of *Ustilago avenae* and ninety-six with the spores of *Ustilago levis*. The same strains and varieties were inoculated in both series with a few exceptions.

As in previous years, *Avena brevis* Roth. and *Avena strigosa* Schreb. gave negative results; *Avena sativa* L. var. *Black Mesdag* (117) and *nigra* (70) also proved free. No smutted plants of *Avena fatua* were observed, but the total number of plants was very small in both series. *Avena sativa* var. *Black Diamond* (116), *C. I. 606* (127), *mutica* (45), *Avena sterilis* var. *Burt* (67) and *Fulghum* (129) gave low infection percentages with both smuts.

Varieties of *Avena nuda* L. again proved very susceptible to both smuts. Other varieties highly susceptible to *Ustilago avenae* were *Avena sativa orientalis* L. var. *Garton's Black* (88), *Avena sativa* var. *Culberson* (120), *Great Dakota* (89), *mutica* (52), and *White Queen* (103). Varieties badly infected with *Ustilago levis* were *Avena sativa orientalis* var. *Garton 748* (109), *Avena sativa* var. *American Banner* (82), *Canadian* (119), *Avena sterilis* var. *Red Rustproof* (98).

Results for 1919.—One hundred and five strains and varieties belonging to nine species were used, both smuts being employed for inoculating different sets of seed. In both cases dry seed was inoculated with dry spores. A large number of rows of some of the varieties that proved free from smut in previous years were planted in order to give these a full test.

Complete freedom from smut was observed in the case of *Avena brevis* (77 and 134), *Avena strigosa* (29 and 133), *Avena ludoviciana* (176), *Avena sativa* var. *aurea* (7), *Black Mesdag* (117), *Krausei* (9), *Monarch* (161), *mutica* (54), *nigra* (70), *Avena sterilis* var. *Burt* (175), *Fulghum* (129), *nigra* (130), *Turkish Rustproof* (267, 268). In addition very low infection occurred in several cases, notably *Avena sativa* var. *mutica* (45 and 57), *Avena sterilis* var. *Burt* (67 and 253) and *Fulghum* (257). Some of these were tested for the first time. Others had been tested one or more years previously.

On looking over the records for all the years the following facts may be specially noted:

1. Altogether one hundred and fifty-four strains and varieties belonging to seven species of *Avena* were inoculated with the spores of *Ustilago avenae*. These strains and varieties were distributed as follows: *Avena brevis* (three), *A. fatua* (three), *A. nuda* (four), *A. sativa* (ninety-nine), *A. sativa orientalis* (twenty-four), *A. sterilis* (eighteen) and *A. strigosa* (three).

2. One hundred and forty-six strains and varieties belonging to the same species were inoculated with the spores of *Ustilago levis*. These were distributed as follows: *Avena brevis* (three), *A. fatua* (three), *A. nuda* (four), *A. sativa* (ninety-three), *A. sativa orientalis* (twenty-two), *A. sterilis* (eighteen) and *A. strigosa* (three).

3. *Avena brevis* Roth. and *A. strigosa* Schreb. proved entirely free from both smuts. *Avena brevis* Roth. (1) was used with *Ustilago avenae* four years and *Ustilago levis* two years; *Avena brevis* (77) with *Ustilago avenae* four years and *Ustilago levis* two years; *Avena brevis* (134) two years with both smuts. *Avena strigosa* Schreb. (29) was tested with *Ustilago avenae* five years and with *Ustilago levis* four years; *A. strigosa* (133) was tested two years with both smuts; *A. strigosa* (76) was tested with *Ustilago avenae* four years and with *Ustilago levis* two years.

4. *Avena sativa* L. var. *nigra* (70) and *A. sativa* var. *Black Mesdag* (117) also proved entirely free from both smuts. The first variety was tested three different years with both *Ustilago avenae* and *Ustilago levis*; *Black Mesdag* was used two years with both smuts. These two are very similar if not identical; the first was received from Doctor Bubak and the second from Doctor Etheridge.

5. Most of the varieties of *Avena sterilis* L. gave very low percentages of infection. Four different strains of Burt oats were tested. Three of these were very slightly infected, the other relatively high. It is doubtful if this strain is really a Burt Oats; it does not resemble very closely the other strains. This is true of the results with both smuts. The *Early Ripe* strain used also proved somewhat susceptible. *Fulghum*, *Italian Rustproof*, *nigra*, *Selection* and *Turkish Rustproof* either gave negative results or very low percentages of infection. Some of these were tested only one year. The strains of *Red Rustproof* proved quite susceptible.

6. The varieties of *Avena nuda* L. were highly susceptible. Generally from sixty to one hundred per cent of the plants were infected with both smuts.

7. There was greater or less variation in the amount of infection

in the varieties of *Avena sativa* L. and *A. sativa orientalis* L. from year to year. Some years a particular variety would prove free from one or both smuts and in other years become more or less infected. One year's tests are not at all conclusive as to the resistance of a variety. When, however, a variety remains free for a succession of years there is good evidence for a high degree of resistance.

8. No apparent differences in the infection capacity of the two species of smuts may be noted. In a given year a variety may be infected slightly or not at all by one smut and severely by the other. The relations may be reversed the following year. It is specially striking that those forms, like *A. brevis*, *A. strigosa*, *A. sativa* var. *nigra* and *Black Mesdag* have proved free from both smuts, that most varieties of *A. sterilis* are only slightly infected by both smuts and that the *A. nuda* group is highly susceptible to both.

GENERAL SUMMARY

In this paper the results of inoculation experiments with powdery mildew, crown rust, loose and covered smuts of oats are reported.

Ninety-eight varieties and strains belonging to fourteen species of *Avena* have been tested with the powdery mildew. Negative results were obtained with only two—*Avena bromoides* and *A. sempervirens*. *Avena brevis* (four strains), *A. fatua* (five strains and varieties), *A. nuda* (three strains and varieties), *A. planiculmis*, *A. pratensis*, *A. purpurea*, *A. sativa* (fifty-one strains and varieties), *A. sativa orientalis* (fourteen strains and varieties), *A. sterilis* (fifteen strains and varieties) and *A. sulcata* gave positive results. In most of these cases complete infection occurred on every inoculated plant. Successful infection of *Arrhenatherum elatius* was also obtained in a few cases. *Holcus lanatus*, *Lolium multiflorum*, *Hordeum vulgare* and *Triticum vulgare* gave negative results. Especially striking is the vigorous infection which occurs on all cultivated varieties of oats.

Including Brentzel's results one hundred and thirty-two strains and varieties belonging to seven species were tested with the crown rust of oats. These were distributed as follows: *Avena brevis* (five), *A. fatua* (six), *A. nuda* (four), *A. sativa* (seventy-one), *A. sativa orientalis* (twenty-two), *A. sterilis* (twenty-one) and *A. strigosa* (three). Of these ninety-two were fully infected in every experiment. *Uredo pustules*, in greater or less number, broke open on every inoculated leaf. In thirty-four additional varieties infection occurred on seventy-five to ninety-nine per cent of the plants inoculated, infection failing on one or more plants in an individual experiment or, rarely, negative results being obtained on all plants in one series. Five varie-

ties had fifty to seventy-four per cent of the inoculated plants infected. The remaining variety, a strain of *Avena brevis*, gave forty-two per cent infection, eleven out of twenty-six inoculated plants being infected. The period of incubation, the number of pustules, their size, shape, etc., were essentially the same on all the varieties. One variety, *Avena sativa* var. *trisperma*, frequently showed a slightly longer incubation period and the development of fewer pustules. So far as seedling inoculation experiments are concerned one is impressed with the very great susceptibility of practically all oat varieties tested to the crown rust.

One hundred and fifty-four varieties and strains belonging to seven species were tested with loose smut during the seasons of 1914, 1916, 1917, 1918 and 1919. Most of these have been tested more than one season. The following gave consistently negative results—*Avena brevis*, *Avena sativa* var. *Black Mesdag* (117) and *nigra* (70) and *A. strigosa*. Most of the varieties of *A. sterilis*, especially Burt, Early Ripe, Fulghum and Selection, have given very low percentages of infection. In any one season several varieties have given negative results but these are not considered significant. When, however, the same variety for two or more years gives negative results or consistently low percentages of infection it must possess great resistance to the parasite. The *Avena nuda* group proved highly susceptible.

One hundred and forty-six varieties and strains were treated with covered smut during 1915, 1916, 1918 and 1919. In general the different species and varieties reacted to this smut in the same way as they did to the loose smut. Varieties highly resistant or susceptible to one smut behaved similarly towards the other.

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F. B. MUMFORD, M. S.
D. W. CHITTENDEN, B. S. in Agr.
PAUL B. BERNARD, B. S. in Agr.
A. T. EDINGER, B. S. in Agr.
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BOTANY

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Cow 13 was in milk during the gestation period in question and was being fed the usual dairy ration for milk production. She was considered a very fat cow for the breed. She was bred May 20, 1913, and was slaughtered January 7, 1914, at which time she was five years and two months old. The fetus from this cow, which was therefore 232 days old, weighed 30.81 pounds. It was analyzed as a composite sample with the exception of the contents of the intestines or excreta, which were handled separately.

Cow 2, bred June 20, 1912, was slaughtered March 26, 1913. Beginning in May 1912, she was fed the usual dairy ration for milk production and at the time of slaughtering was in better condition of flesh than the average cow at this stage of pregnancy. This fetus was about a full term calf, having been carried 279 days. The operation of slaughtering was delayed as long as it seemed safe to do so and still be able to obtain all the fluids and other parts without loss. This calf fetus was normally developed and weighed a little over sixty-nine pounds. It was analyzed as a composite sample without any separation into parts.

Jersey Cow 11 (Missouri St. Lambert) furnished consecutively two calves at birth for this experiment, both of which were born dead. This cow was a little over eleven years old at the time of birth of the first calf, No. 11A. She had previously suffered from prolapsus which may have had something to do with the calves being still-born. She was used as a family cow and was fed a usual ration for milk production during both of these gestation periods. The first calf, No. 11A, was ground to make one composite sample. The second calf, No. 11B, was divided into a number of samples as indicated in the tables. Since the calf was dead before being handled it was not possible to obtain a complete sample of the blood, but the sample obtained was mingled with other body liquids and serum. In addition to the separate samples, a sample representing the entire calf was obtained by mixing together aliquots of the separated and weighed parts and passing the mixture thru a meat grinder a few times to insure a uniform mixture.

Cow 22 was three years and three months old at the time of the birth of the bull calf analyzed. At this time she was still immature and growing steadily. She was in milk during the twelve months preceding and was being fed as good a ration as possible for growth and milk production. The calf in question was dropped June 15, 1912, and weighed 57 pounds. This calf was weaker than the average calf altho able to stand. It was slaughtered June 20, 1912, at which time it weighed 52.2 pounds. This animal

was divided into six samples for analysis, as indicated in the tables.

Heifer 85 was used in an experiment to determine the effect of a deficiency of mineral in the feed. At six months of age she was put upon a ration of silage and grain. The latter consisted of gluten meal, three parts; and corn, two parts. When silage was not available timothy hay was fed in its place. While sufficient for growth and energy this ration was deficient in calcium, supplying approximately about ten grams a day. Up to the twelfth month on this ration body weight and growth in skeleton appeared to be normal; after this, however, symptoms of distress, such as stiffness of the joints, became apparent, probably due to the low calcium supply. One month after the first appearance of the symptoms the animal was practically unable to stand. The feed was changed to alfalfa hay with calcium carbonate and bone meal fed in addition. This change in feed was made about January 1, 1914. She recovered slowly up to the time of calving four months later when she was in a fair condition. The calf from Heifer 85 was born May 2, 1914, and weighed 30 pounds at birth. This calf was abnormal, the lower jaw was undeveloped, there were no eyes, and hair was growing from the eye sockets. Twelve hours after birth it was slaughtered. The whole animal exclusive of the blood was composited into one sample for analysis. The blood was analyzed as a separate sample.

To summarize, the weights of these embryonic and full-term calves are indicated in Table 1.

TABLE 1.—WEIGHTS OF JERSEY CALVES AS OBTAINED FOR THIS EXPERIMENT

Description	Pounds	Grams
Fetus of Cow 43 (185 days) 43X	14.48	6,568
Fetus of Cow 13 (232 days) 13X	30.81	13,975
Fetus (full term) of Cow 2 (279 days) 2X	69.81	31,665
Calf of Cow 11 (stillborn) 11A	56.00	24,040
Calf of Cow 11 (still born) 11B	70.40	31,933
Calf of Cow 22 (5 days old) 22A	52.20	23,677
Calf of Heifer 85 (abnormal) 85A	30.00	13,608

B. THE HEREFORD COWS AND THEIR CALVES

The dams of the pure-bred Hereford calves discussed in this report were kept on three different planes of nutrition, as follows: Heifers 560, 561, and 562 were kept on a high plane of nutrition; heifers 563, 564 and 565, on a medium plane of nutrition; and heifers 566, 567 and 568, on a low plane of nutrition. All of the animals were fed a grain ration of six parts of corn, three parts of

bran, and one of linseed, with roughage consisting of three parts of alfalfa hay and two parts of oat straw. The animals on the high plane of nutrition were allowed to eat enough of this ration to fatten as well as to make thrifty growth; those on the medium plane, enough to make thrifty growth without getting fat; and those on the low plane were fed scantily in order to keep them in the condition of cattle on a Southwest range under arid conditions. The feeding was so adjusted that the animals were eating all of the roughage they desired and the condition was regulated by the amount of grain fed. By this arrangement the heifers on the high plane of nutrition on the average received two parts of grain to one of roughage; those on the medium plane, one-third to one-fourth as much grain as roughage; while those on the low plane received roughage alone most of the time with occasionally a little grain. The feeding of these Hereford heifers began in August, 1912.

All of these heifers were bred after they had become established upon their respective planes of nutrition. Under the condition of scanty feeding to which the low-plane heifers were subjected these failed to come into heat promptly. The plane of feeding was therefore raised for a time so that the animals came in heat. After breeding the plane of feeding was again dropped to the original level.

The calves produced by these heifers on the three planes of nutrition were slaughtered soon after birth and analyzed. It was hoped that the data thus obtained would indicate whether the different planes of nutrition of the mother heifer had any effect upon the composition of the calf at birth, and, if so, how much.

Heifer 561 died at the time of the first calving, and this calf was not analyzed.

The calves have been given the same number as the heifer dam with an accompanying letter, A, B, etc., corresponding to the first, second, etc., calf dropped by the heifer since the beginning of the experiment.

Heifer 560 was found to have been bred before the opening of the experiment. The calf designated as 560A was dropped in November, 1912, but was not analyzed. The heifer was immediately dried up and continued in the experiment.

In handling the new-born Hereford calves it was the intention to slaughter them before they received any food from the mother. This was accomplished, with one exception, namely in case of Calf 565B.

All of these Hereford calves reported upon in this bulletin appeared to be normal in development. The calves from the heifers on the high plane of nutrition had smoother appearance according to the animal-husbandry judges. The calves from the heifers on the medium plane of nutrition appeared to be as vigorous, on the average, as calves usually are at birth. Calf 568B, the lightest of all, from the low-plane group, while normally developed, was the weakest of all the calves. This calf did not stand upon its feet before slaughtering. On the other hand, Calf 566B, also from the low-plane group, was practically as heavy as any calf obtained in this experiment, and Calf 567B of average weight and vigor appeared to have about as much internal and carcass fat as any of the calves from the better fed groups.

The mesentery from Calf 565A was covered with fat sufficient only to make it opaque.

The analysis of the excreta of Calf 565B was not made, as milk was found in the stomach of this calf.

Table 2 gives the list of Hereford calves analyzed, with their respective live weights at birth.

TABLE 2.—LIVE WEIGHT OF HEREFORD CALVES AT BIRTH

Calf No.	Plane of Feeding	Live Weight	
		Pounds	Grams
560B	High Plane	88.25	40,029
562B	High Plane	82.38	37,364
560D	High Plane	71.75	32,545
562C	High Plane	87.75	39,803
565A	Medium Plane	89.48	40,587
563A	Medium Plane	89.64	40,661
564B	Medium Plane	67.82	30,760
565B	Medium Plane	72.43	32,854
564C	Medium Plane	85.00	38,555
568B	Low Plane	39.00	17,690
567B	Low Plane	63.00	28,576
566B	Low Plane	89.00	40,370
568C	Low Plane	73.80	33,478

METHODS OF SLAUGHTERING AND SAMPLING

All of the calves at birth were slaughtered in from four to ten hours after birth with the exception of the calf of Jersey Cow 22 which was five days old when slaughtered. In the operation of slaughtering the animal was stunned and suspended by the hind legs from a hoist. The throat was then opened up in the usual manner and the animal bled as thoroly as possible, the blood be-

ing caught in a tared container and weighed. A portion of the blood was caught in a beaker and samples for analysis were poured into tared containers which were immediately closed tight, taken to the laboratory and weighed.

After bleeding, the feet were skinned out, removed from the carcass, weighed and placed in a closed container. Also the head and tail, after removal of the hide from these parts, were cut off and weighed. The body was then opened along the ventral line and the internal organs including the kidneys were removed, placed in a tight container and a little later separated from each other and then weighed. The contents of the intestinal tract were removed, weighed, and set aside in a closed container for analysis as excreta. The cleaned intestines were put with the internal organs.

After the removal of the internal organs the carcass of the calf, the hide still on, was allowed to chill out for some hours in a cooler. When completely cold the hide was skinned off carefully to avoid, as far as possible, the removal of sub-dermal tissue with it. After weighing the hide that part from the right half of

TABLE 3.—COMPARISON OF THE LIVE WEIGHT OF DIFFERENT CALVES FROM THE SAME HEIFER, IN POUNDS

	First Calf	Second Calf	Third Calf	Fourth Calf
Heifer 560	*71.50	88.25	*88.00	71.74
Heifer 562	*89.00	82.38	87.75	.....
Heifer 564	*83.00	67.82	85.00	.....
Heifer 565	89.48	72.43	.....	.....
Heifer 566	*72.50	89.00	.....	.....
Heifer 567	*69.50	63.00	.....	.....
Heifer 568	*59.00	39.00	73.80	.....

*From data of Animal Husbandry Department, Mo. Agr. Expt. Sta.

the animal was cut into strips and ground to a uniform sample in a meat chopper. The head was split into right and left halves; the brain was then removed and weighed. The carcass was also split thru the middle of the backbone, the spinal cord was removed and weighed. The brain and spinal cord were then added to the internal organs obtained as above described and all of these ground to a uniform sample for analysis as composite internal organs. The tail was split into right and left halves and the lean and fat flesh were removed as carefully as possible from the right half of the head, tail, and carcass respectively and together with the right kidney fat of the carcass weighed as composite flesh, right half.

The flesh thus obtained was ground to a uniform sample in a meat grinder. The bones thus cleaned from the right half of the head, the tail, and the right half of the body including the right fore and right hind foot constituted the skeleton, right half. This was passed thru a bone grinder to reduce the sample to a fine condition for analysis. The weights recorded in the tables for composite flesh and composite skeleton are for the entire animal obtained by taking twice the weights for the right half.

With a number of the animals, in addition to these samples, three special samples were taken for analysis from the left side

TABLE 4.—WEIGHTS OF SEPARATED PARTS OF NEW BORN JERSEY CALVES, IN GRAMS

Animal No.	11 B.	22A.	85A.*
Live weight of animal	31,933.0	23,677.0	13,608
Blood	1,675.0	1,015.8	555
Hair and hide	3,896.0	2,224.0	.....
Composite flesh	12,862.0	8,610.0	.....
Tongue with base	237.0	166.0	.....
Esophagus .....	.....¹	20.0	.....
Thymus and thyroid	120.0	57.0	.....
Lungs and trachea	218.0	432.0	.....
Heart	256.0	123.0	.....
Pericardium and arteries	169.0 ²	90.0	.....
Diaphragm .....	.....	99.0	.....
Stomachs	467.0	333.0	.....
Spleen	124.0	82.0	.....
Liver	581.0 ³	543.0	.....
Gall bladder .....	.....	1.0	.....
Gall .....	.....	2.0	.....
Pancreas .....	.....	21.0	.....
Small intestines .....	.....	580.0	.....
Large intestines .....	.....	224.0	.....
Bladder	1,215.0	20.0	.....
Urine .....	.....	36.0	.....
Penis .....	.....	55.0	.....
Testicles .....	.....	9.0	.....
Kidneys	193.0	106.0	.....
Fat of stomach and intestines	168.0	80.0 ⁴	.....
Brain	257.0	200.0	.....
Spinal cord	81.0	56.0	.....
Total internal organs	4,086.0	3,299.0	.....
Composite skeleton	7,554.0	6,405.6	.....
Excreta	301.0	383.0	.....
Kidney fat	200.0	59.0	.....
Length of small intestine, cms.	1,745.0	1,602.0	.....
Length of large intestine, cms. ....	.....⁵	223.0	.....

¹Esophagus weighed with stomach.

²Diaphragm weighed with pericardium and arteries.

³Includes gall bladder and gall.

⁴Length not recorded.

⁵Mesentery only.

⁶Blood was the only part separated and weighed.

of the carcass in order that some data regarding the composition of these tissues at birth might be secured. These samples were the marrow from the femur, the left kidney fat, and lean flesh of the loin as free as possible from fatty or connective tissues.

The first calf obtained for analysis, 560B, on the high plane of nutrition, was strangled at birth and could not be bled. All of the soft parts—lean and fat flesh of body, internal organs, and the blood—were composited into one sample, the bones, teeth, and hoofs were composited for the second sample; the hair and hide constituted the third sample; and the intestinal contents or excreta, the fourth sample. On this last sample no analysis of the fresh material was made.

Calf 560D was obtained by post mortem operation on the mother, Cow 560. Some days before full term, the cow was taken sick with symptoms of labor pains and general distress. The symptoms were alleviated by the veterinarian but the cow finally died on the day the calf was due. The cause of the trouble was not found. This calf was normal and apparently alive when the mother cow died. It, of course, could not be bled, but the blood remained with the tissues, a part with the flesh, but the larger

TABLE 5.—PERCENTAGE OF LIVE WEIGHT OF SEPARATED PARTS OF NEW-BORN JERSEY CALVES

Animal No.	11B.	22A.	85A. ^a	Average
Live weight of animal	100.00	100.00	100.00	100.00
Blood	5.24	4.29	4.08	4.54
Hair and hide	12.20	9.39	.....	10.80
Composite flesh	40.28	36.36	.....	38.32
Lungs and trachea	0.68	1.82	.....	1.25
Heart	0.80	0.52	.....	0.66
Pericardium and arteries	0.53 ^b	0.38	.....	0.46
Diaphragm .....	.....	.42	.....	.....
Stomachs	1.46	1.41	.....	1.44
Liver	1.82 ^a	2.29	.....	.....
Large and small intestine	3.36 ^c	3.40	.....	3.38
Kidneys	0.60	0.45	.....	0.53
Fat of stomach and intestines	0.53	0.34 ^d	.....	.....
Brain and spinal cord	1.06	1.08	.....	1.07
Total internal organs	12.80	13.94	.....	13.37
Composite skeleton	23.60	27.06	.....	25.33
Excreta	0.94	1.62	.....	1.28
Kidney fat	0.63	0.25	.....	0.44

^aDiaphragm weighed with pericardium and arteries.

^bGall bladder and gall included.

^cObtained by calculation.

^dMesentery only.

^eBlood was the only part separated and weighed.

part appeared to be in the internal organs. The kidney fat was not added to the flesh as usual, but remained a separate sample.

All the other calves analyzed were divided into six regular and three special samples for analysis, but not all of the special samples were taken in every case.

WEIGHTS AND PROPORTIONS OF PARTS

THE JERSEY CALVES

The weights of the separated parts are shown in Table 4, and the proportions to the total live weight of the animal are shown in Table 5. The weight of the blood varies from approxi-

TABLE 6.—WEIGHTS IN GRAMS OF SEPARATED PARTS OF NEW-BORN HEREFORD CALVES FROM DAMS ON A HIGH PLANE OF NUTRITION

Animal No.	560B.	562B.	560D.	562C.
Live weight of animal	40,029.0	37,364.0	32,545.0	39,803.0
Blood	90.7 ¹	1,746.4	.....²	1,777.5
Hair and hide	4,590.0	4,620.9	4,130.5	4,323.3
Composite flesh	19,180.0*	15,518.4	13,120.1	16,578.7
Tongue with base	307.0	212.7	238.1	292.0
Esophagus	91.0	56.7	45.4	48.2
Thymus and thyroid glands	135.0	141.8	184.2	192.8
Lungs	779.0 ^{2*}	343.1 ²	910.0	360.0
Heart	343.0 ⁴	212.6	243.8	212.6
Pericardium and arteries .....	.....⁵	170.1	175.8	167.3
Diaphragm .....	.....⁵	42.5	34.0	25.5
Stomachs	427.0	377.0	377.1	320.3
Spleen	92.0	76.5	113.4	76.5
Liver	902.0	666.2	793.8 ⁶	788.1
Gall bladder and gall	10.0	14.2	.....⁷	19.9
Pancreas	41.0	34.0	34.0	31.2
Small intestines	654.0	691.7	510.3	584.0
Large intestines	227.0	212.6	226.8	283.5
Bladder	73.0	73.7	.....⁸	45.4
Urine	155.0	53.8	.....⁸	158.7
Penis and testicles .....	.....⁹	51.0	.....	.....
Uterus, ovaries, tubes, etc. ....	.....	.....	133.2 ⁷	70.9
Serum and body liquids	1,932.0	.....⁸	581.2	.....⁸
Kidneys	311.0*	102.1	93.6	181.4
Fat of stomach and intestines .....	.....⁹	241.0	178.6	207.0
Brain	218.0	204.1	198.5	207.0
Spinal cord	130.0	73.7	65.2	82.2
Total internal organs .....	.....⁹	4,051.1	5,137.0	4,354.5
Composite skeleton	9,252.0	9,854.2	8,660.7	11,682.8
Excreta	1,019.0	402.6	532.9	782.4
Kidney fat .....	.....⁹	.....⁹	218.3	232.5
Length of small intestines, cms....	1,425.0	1,242.0	1,406.0	1,232.0
Length of large intestines, cms....	242.0	228.0	246.0	220.0

*Weight doubtful.

¹A portion of the blood.

²This sample includes the trachea.

³Not obtained separately.

⁴Includes the pericardium and arteries.

⁵Includes the gall bladder and gall.

⁶No sum—all parts were not weighed.

⁷Includes the bladder and urine.

mately 4 per cent to 5.2 per cent. A part of this variation may be due to the fact that the blood from the first Jersey calf was not obtained pure but was mixed with water and serum. The hair and hide, wind-pipe and lungs, and heart show a wide variation. The first Jersey calf, 11B, is of average development and weight, while the second calf, 22A, was undersized, underweight and of less vigor. This latter calf, therefore, may be expected to show a lower proportion of flesh and higher proportion of skeleton than the first calf. This accords with the actual results obtained.

TABLE 7.—WEIGHTS IN GRAMS OF SEPARATED PARTS OF NEW-BORN HEREFORD CALVES FROM DAMS ON A MEDIUM PLANE OF NUTRITION

Animal No.	565A	563A	564B	565B	564C
Live weight of animal	40,587.0	40,661.0	30,760.0	32,854.0	38,555.0
Blood	1,805.3	1,958.6	1,862.0	1,672.6	2,044.0
Hair and hide	4,990.0	5,848.0	3,720.0	4,019.9	4,031.3
Composite flesh	16,556.0	14,906.0	11,032.0	13,016.3	16,034.4
Tongue with base	240.0	349.0	235.0	235.3	255.2
Esophagus	47.0	38.0	.....¹	28.3	59.5
Thymus and thyroid glands	150.0	100.0	49.0 ⁴	164.4	147.5
Lungs	534.0 ¹	386.0 ¹	328.0	269.3	425.2
Heart	233.0	224.0	182.0	170.1	229.6
Pericardium and arteries	222.0	287.0	242.0	136.1	161.6
Diaphragm	62.0	170.0	.....⁴	22.7	36.9
Stomachs	360.0	326.0	356.0	294.8	382.7
Spleen	64.0	58.0	46.0	51.0	70.9
Liver	682.0	642.0	634.0	595.3	686.1
Gall bladder and gall	13.0	12.0	3.0	2.8	22.7
Pancreas	17.0	26.0	23.0	28.4	34.0
Small intestines	732.0	698.0	859.0	635.0	782.4
Large intestines	284.0	216.0	274.0	241.0	255.1
Bladder	48.0	42.0	43.0	22.7	56.7
Urine	33.0 ²	25.0	250.0	76.5	311.8
Penis	65.0	.....	52.0	.....	.....
Testicles	12.0	.....	8.0	.....	.....
Uterus, ovaries, tubes, etc. ....	.....	236.0	.....	62.4	113.4
Kidneys	110.0	119.0	101.0	93.6	150.2
Fat of stomach and intestines	190.0	122.0	141.0	184.3	189.9
Brain	224.0	235.0	228.0	207.0	235.3
Spinal cord	99.0	61.0	63.0	65.2	85.1
Total internal organs	4,388.0	4,372.0	4,117.0	3,586.2	4,691.8
Composite skeleton	11,156.0	10,804.0	8,054.0	8,708.9	10,636.7
Excreta	709.0 ³	641.0	326.0	479.1	479.1
Kidney fat .....	.....⁵	120.0	.....⁵	.....⁵	93.6
Length of small intestines cms.	1,323.0	1,387.0	1,612.0	1,504.0	1,776.0
Length of large intestines, cms.	205.0	242.0	202.0	237.0	246.0

¹This sample includes trachea.

²Weight of excreta includes the urine.

³Weighed with pericardium and arteries.

⁴Thyroid only. Thymus with pericardium and arteries.

⁵Not weighed separately.

⁶Diaphragm with pericardium and arteries.

THE HEREFORD CALVES

Tables 6, 7, and 8 give the weights of parts, and Tables 9, 10, and 11 give the percentages. The average values from Tables 5, 9, 10, and 11 are grouped together in Table 12 for ready comparison. The weights of the blood obtained from eleven of the thirteen Hereford calves range from 4.34 per cent to 6.05 per cent of the live weight, with an average value of 4.93 per cent. The weights of hair and hide vary irregularly between 10.46 and 14.38 per cent.

The composite flesh varies within wide limits from 29.54 per

TABLE 8.—WEIGHTS IN GRAMS OF SEPARATED PARTS OF NEW-BORN HEREFORD CALVES FROM DAMS ON A LOW PLANE OF NUTRITION

Animal No.	568B	567B	566B	568C
Live weight of animal	17,690.0	28,576.0	40,370.0	33,478.0
Blood	912.0	1,335.4	2,104.9	1,451.5
Hair and hide	2,477.0	3,415.5	4,856.2	3,657.1
Composite flesh	5,226.0	11,124.3	15,750.9	12,898.9
Tongue with base	144.0	286.3	246.6	297.7
Esophagus	47.0	42.5	53.8	48.2
Thymus and thyroid glands	29.0	110.6	45.4 ¹	116.2
Lungs	210.0	249.5	297.7	408.2
Heart	110.0	172.9	232.5	189.9
Pericardium and arteries	102.0	99.2	172.9	121.9
Diaphragm	65.0	48.2	28.3	42.5
Stomachs	208.0	252.3	354.5	374.2
Spleen	27.0	53.9	62.4	56.7
Liver	240.0	504.6	646.4	493.3
Gall bladder and gall	7.0	11.3	17.0	25.5
Pancreas	12.0	.....²	34.0	34.0
Small intestines	346.0	516.0	785.3	756.9
Large intestines	125.0	198.4	283.5	266.5
Bladder	21.0	51.0	42.5	90.7 ³
Urine	162.0	73.7 ³	133.2	.....
Penis	52.0	45.4	45.4	.....
Testicles	4.0	14.2	17.0	.....
Uterus, ovaries, tubes, etc. ....	.....	.....	.....	136.1
Serum and body liquids .....	.....⁴	.....⁴	17.0	48.2
Kidneys	70.0	79.4	127.6	93.6
Fat of stomach and intestines	182.0	153.1	178.6	170.1
Brain	190.0	221.1	226.8	215.5
Spinal Cord	44.0	73.7	85.0	62.4
Total Internal Organs	2,397.0	3,183.6	4,133.4	4,048.3
Composite skeleton	5,148.0	8,513.3	12,224.3	9,786.2
Excreta	280.0	584.0 ³	280.7	671.9
Kidney fat	72.0	.....⁴	192.8	107.7
Length of small intestines, cms.	1,129.0	1,257.0	1,518.0	1,458.0
Length of large intestines, cms.	179.0	214.0	241.0	212.0

¹One gland only. The other gland weighed with pericardium.

²With fat of intestines.

³Weight of excreta includes the urine.

⁴Not weighed separately.

⁵Includes weight of urine.

cent in the smallest calf to 41.59 per cent in one of the large calves. The average value for twelve Hereford calves is 38.67 per cent. The abnormally high percentage of the flesh of Calf 560B may be partly due to the fact that the blood was not drawn but remained in and was weighed with the soft parts. This high percentage,

TABLE 9.—PERCENTAGE OF LIVE WEIGHT OF SEPARATED PARTS OF NEW-BORN HEREFORD CALVES FROM DAMS ON A HIGH PLANE OF NUTRITION

Animal No.	560B	562B	560D	562C	Average
Live weight of animal	100.00	100.00	100.00	100.00	100.00
Blood .....	.....¹	4.68	.....¹	4.47	4.58
Hair and hide	11.47	12.37	12.69	10.86	11.85
Composite flesh	47.91 ¹	41.53	40.31	41.65	41.16
Lungs	1.95 ¹	0.92	2.80 ¹	0.90	0.91
Heart, pericardium and arteries	0.86	1.02	1.29	0.95	1.03
Stomachs	1.07	1.01	1.16	0.80	1.01
Spleen	0.23	0.20	0.35	0.19	0.24
Liver	2.25	1.78	2.44 ¹	1.98	2.00
Pancreas	0.10	0.09	0.10	0.08	0.09
Large and small intestines	2.20	2.42	2.27	2.18	2.27
Kidneys	0.77 ¹	0.27	0.29	0.46	0.34
Brain and spinal cord	0.87	0.74	0.81	0.73	0.79
Total internal organs .....	.....¹	10.84	15.78 ¹	10.94	10.89
Composite skeleton	23.11	26.38	26.61	29.35	26.36
Excreta	2.54	1.08	1.64	1.97	1.81

¹Omitted from average.

²Data on some parts missing.

³Includes the gall bladder and gall.

⁴Not obtained separately.

TABLE 10.—PERCENTAGES OF LIVE WEIGHT OF SEPARATED PARTS OF NEW-BORN HEREFORD CALVES FROM DAMS ON A MEDIUM PLANE OF NUTRITION

Animal No.	565A	563A	564B	565B	564C	Average
Live weight of animal.....	100.00	100.00	100.00	100.00	100.00	100.00
Blood	4.45	4.82	6.05	5.09	5.30	5.14
Hair and hide	12.29	14.38	12.09	12.24	10.46	12.29
Composite flesh	40.79	36.66	35.86	39.62	41.59	38.90
Lungs	1.32	0.95	1.07	0.82	1.10	1.03
Heart, pericardium and arteries	1.12	1.26	0.59	0.93	1.07	1.10
Stomachs	0.89	0.80	1.16	0.89	0.99	0.95
Spleen	0.16	0.14	0.15	0.15	0.18	0.16
Liver	1.68	1.58	2.06	1.81	1.78	1.78
Pancreas	0.04	0.06	0.08	0.08	0.08	0.07
Large and small intestines	2.50	2.25	3.68	2.66	2.69	2.76
Kidneys	0.27	0.29	0.33	0.28	0.39	0.31
Fat of stomach and intestines	0.47	0.30	0.46	0.56	0.49	0.45
Brain and spinal cord	0.80	0.73	0.95	0.83	0.83	0.83
Total internal organs	10.81	10.75	13.38	10.92	12.17	11.61
Composite skeleton	27.49	26.57	26.18	26.51	27.59	26.87
Excreta	1.75	1.57	1.06	1.46	1.24	1.42

however, does not show with Calf 560D which was handled in the same manner.

The weight of the total internal organs varies from 10.24 per cent to 13.55 per cent of the live weight. The high value, 15.78 per cent, for calf 560D which is not included in the average is of

TABLE 11.—PERCENTAGE OF LIVE WEIGHT OF SEPARATED PARTS OF NEW-BORN HEREFORD CALVES FROM DAMS ON A LOW PLANE OF NUTRITION

Animal No.	568B	567B	566B	568C	Average
Live weight of animal	100.00	100.00	100.00	100.00	100.00
Blood	5.16	4.67	5.21	4.34	4.85
Hair and hide	14.00	11.95	12.03	10.92	12.23
Composite flesh	29.54	38.93	39.02	38.53	36.51
Lungs	1.19	0.87	0.74	1.22	1.01
Heart, pericardium and arteries	1.20	0.95	1.00	0.93	1.02
Stomachs	1.18	0.88	0.88	1.12	1.02
Spleen	0.15	0.19	0.15	0.17	0.17
Liver	1.36	1.76	1.60	1.47	1.55
Pancreas	0.07	.....¹	0.08	0.10	0.08
Large and small intestines	2.66	2.49	2.64	3.06	2.71
Kidneys	0.39	0.28	0.32	0.28	0.32
Fat of stomach and intestines	1.03	0.54	0.44	0.51	0.63
Brain and spinal cord	1.32	1.03	0.77	0.83	0.99
Total internal organs	13.55	11.14	10.24	12.09	11.76
Composite skeleton	29.10	29.79	30.28	29.23	29.60
Excreta	1.58	2.04	0.70	2.01	1.58

¹With fat of intestine.

TABLE 12.—AVERAGE PERCENTAGE VALUES FOR THE SEPARATED PARTS OF THE JERSEY AND HEREFORD CALVES

	Jersey Calves		Hereford Calves		
	All calves	High plane	Medium plane	Low plane	All calves
Live weight	100.00	100.00	100.00	100.00	100.00
Blood	4.54	4.58	5.14	4.85	4.93
Hair and hide	10.80	11.85	12.29	12.23	12.13
Composite flesh	38.32	41.16	38.90	36.51	38.67
Lungs	1.25	.91	1.03	1.01	1.01
Heart, pericardium and arteries	1.12	1.03	1.10	1.02	1.05
Stomachs	1.44	1.01	.95	1.02	.99
Spleen .....	.....¹	.24	.16	.17	.19
Liver .....	.....¹	2.00	1.78	1.55	1.76
Pancreas .....	.....¹	.09	.07	.08	.08
Large and small intestines	3.38	2.27	2.76	2.71	2.60
Kidneys	0.53	.34	.31	.32	.32
Fat of stomach and intestines .....	.....¹	.....¹	.45	.63	.....¹
Brain and spinal cord	1.07	.79	.83	.99	.86
Total internal organs	13.37	10.89	11.61	11.76	11.53
Composite skeleton	25.33	26.36	26.87	29.60	27.55
Excreta	1.28	1.81	1.42	1.58	1.59

¹Not calculated.

course explained by the fact that a large part of the blood is with this sample. The composite skeleton varies from 26.18 per cent to 30.28 per cent of the live weight. These calves represent different degrees of development and vigor about in proportion to their live weight. The heavier calves show a lower proportion of internal organs and of skeleton and a higher proportion of flesh to the live weight than do the lighter calves. The variations in the other parts are due probably to difficulties in making a uniform separation of the parts or to individuality.

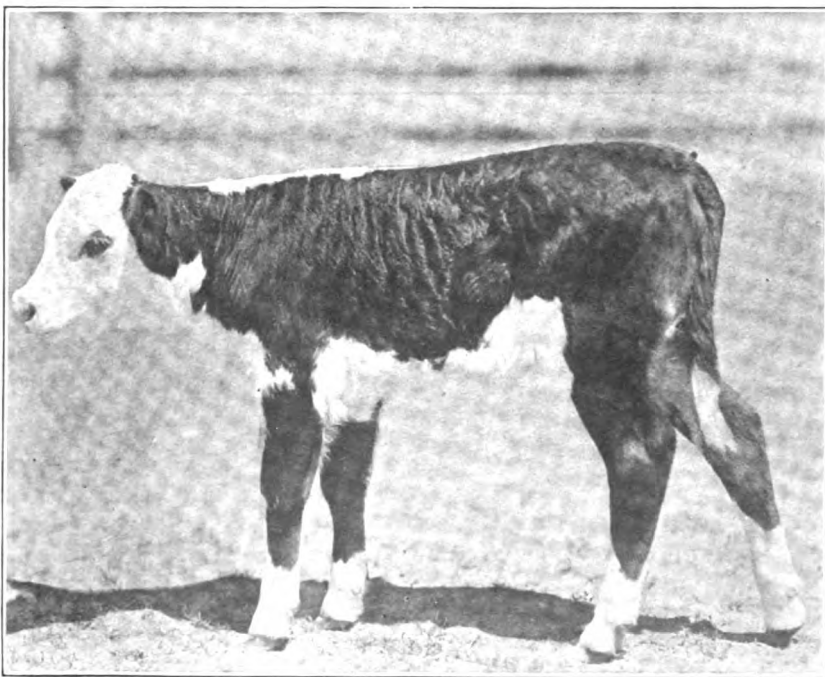
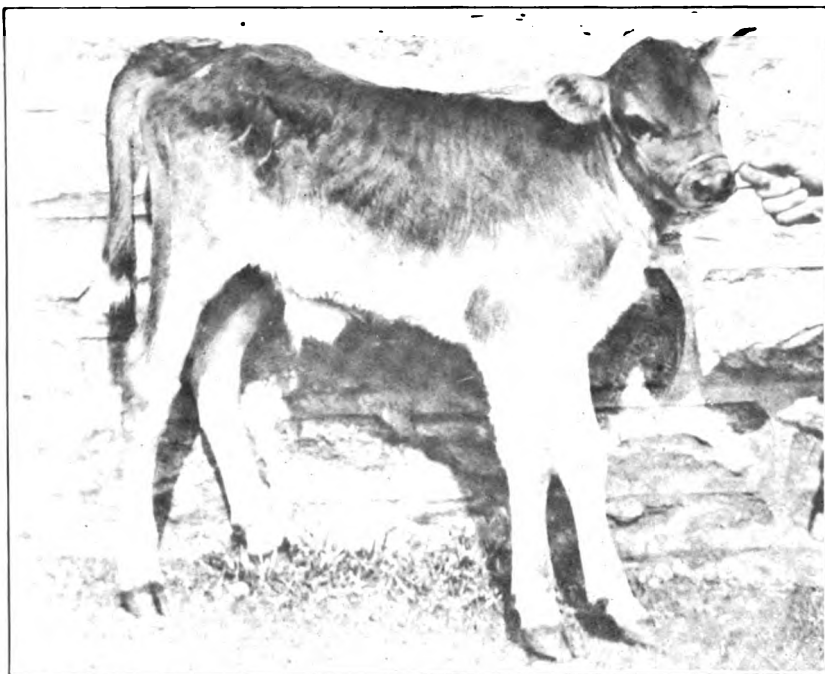
THE JERSEY AND HEREFORD CALVES COMPARED

The proportion of blood to live weight of animal seems to be the same for both breeds. However, two Jersey calves show the lowest percentage, 4.08* and 4.29 per cent, and two Hereford calves the highest values, 6.05 and 5.30 per cent. The other nine Hereford calves all show a lower proportion of blood to live weight than the other Jersey calf, 11B. It is evident that these variations in the proportion of blood have nothing to do with the breed of the animal.

The percentage of the hair and hide of the Jersey calves show one high and one low value. Seven of the Hereford calves give values which are lower or about equal to the higher value of the Jersey calf, while all the rest exceed it. For all the Hereford calves the average percentage of the weight of the hair and hide is 12.13 per cent, which is higher than the highest value of the Jersey calf. It thus appears that in general the hide and hair from the Jersey calves is a lower proportionate part of the live weight than is the hair and hide of the Hereford calves. Data on mature animals give the same results. It is evident that the Jersey is a thinner skinned animal than the Hereford.

The weight of composite flesh in the Jersey calves shows intermediate values as compared with the highest and lowest of the Hereford calves. Six of the Hereford calves show higher proportionate value than the highest value for Jersey calves, and two other Hereford calves, 564B and 568B, show lower proportionate values than the lowest value of the Jersey calves. Doubtless the same number of Jersey calves representing the same variations in condition that we have in the Hereford calves would show the same variations in the percentage of weight of flesh to live

*This value is from Calf 85A for which only the weights of animal and blood were obtained. See Table 15.



Typical Jersey and Hereford calves as they appear shortly after birth

weight as are shown with the Hereford calves. The average percentage value for composite flesh for all the Herefords is in close agreement with the average value for the two Jerseys.

For the total internal organs, omitting Hereford Calf 560D for reasons stated above, one Jersey calf shows the highest proportionate value, or 13.94 per cent. Nine Hereford calves show a lower value than the lowest Jersey value—12.80 per cent. Two Hereford calves show values intermediate between the values of the two Jersey calves. From the data it would appear that the internal organs of the Jerseys show a higher value in proportion to the live weight than do the internal organs of the Herefords. More data on Jersey calves should be forthcoming for positive proof.

Among the proportions of the separated organs the fairly uniform values for heart and kidneys of all the animals may be noted. The most striking variation as regards organs between the two breeds is the higher proportionate weight of the stomach and intestines of the Jerseys as compared to the Herefords. The two values for the stomachs of the Jerseys were 1.46 and 1.41 per cent as compared with values for the stomachs of the Herefords which range from 0.80 to 1.18 per cent, or an average value for all the Herefords of 0.99 per cent. The weight for intestines of Calf 11B, 1215 grams, includes the weight of the pancreas, bladder, penis and testicles. If we deduct from this weight the proportional weight of these organs as found in Calf 22A we obtain a calculated weight of intestines for Calf 11B amounting to 3.36 per cent of the live weight of 11B. Both this value and the value 3.40 per cent for Calf 22A are appreciably above the values for twelve of the Hereford calves which range from 2.18 to 3.06 per cent with an average of all values of 2.60 per cent. Calf 564B is a notable exception in the proportionate weight of the intestines to the live weight. The value found, 3.68 per cent, is in close agreement with the corresponding values found for the Jerseys.

The size of the intestines may be judged by their length, especially the small intestines. The length of the large intestine seems to show but little variation in the different animals. The lengths of the small intestine of the Jersey calves were 1745 and 1602 centimeters, or an average value of 1674 centimeters. The length of the small intestines of eleven Hereford calves ranges from 1129 to 1518 centimeters, while the other two Herefords calves, 564B and 564C, give values for length of 1612 and 1776 centimeters respectively. The average value for the eleven Herefords is 1353 centimeters. It seems quite reasonable that the dairy type

of bovine should be provided with a digestive apparatus of larger capacity than the beef type because of the large amount of roughage consumed by the dairy animal. The new born calf shows, therefore, the effect of this high amount of roughage fed thru succeeding generations in the size of the digestive tract with which it is provided. It is significant that Hereford Cow 564, the mother of the two calves, 564B and 564C, proved to be an unusually good milker for her breed. She therefore seems to approach the dairy type of animals and her calves show the high capacity of the alimentary tract of the dairy calf.

The Hereford calves show all ranges from the lowest to the highest in proportionate weight of skeleton. The results for the two Jersey calves are one low and one average result. This does not seem to indicate that the skeleton of the Jersey is necessarily lighter in proportion to the live weight than is the skeleton of the Hereford. A larger number of Jerseys might show the same range of values as is shown by the Herefords here reported.

THE EFFECT OF THE PLANE OF NUTRITION UPON THE WEIGHTS OF THE PARTS OF THE ANIMALS

Of the Herefords, four are from mothers on high planes of nutrition, five are from mothers on medium planes of nutrition, and four are from mothers on low planes of nutrition. The mothers of the two Jersey calves were on planes of nutrition which for our purposes may be considered a medium plane.

The weight of blood obtained from the various calves shows no relation whatever to the plane of feeding upon which the mother was kept. This is shown by the average percentages for the three groups, 4.58, 5.14, and 4.85 per cent. Calf 564B, medium plane, furnished the highest result, 6.05 per cent, while Jersey Calf 22A, also a medium plane, gave the lowest result, 4.28 per cent. Jersey Calf 85A, fed abnormally, furnished a low result, 4.08 per cent. It is hardly fair, however, to compare this with other medium-plane calves. Of the low results for the Hereford calves, 4.47 per cent, 4.45 per cent, and 4.34 per cent, one comes from each plane of nutrition.

Comparing the average percentage for each group no relation appears between the plane of nutrition and the percentage of the hair and hide. Both the highest and the lowest percentages, 14.38 per cent for Hereford Calf 563A, and 9.39 per cent for Jersey Calf 22A, are from the medium-plane group, while two of the low-plane Hereford calves, 568B and 568C, give also a high and a low result,

14.00 per cent and 10.92 per cent, respectively. The high-plane calf, 562B, gives the result 12.37 per cent, which compares very closely with three other medium-plane animals, 12.20, 12.09 and 12.24 per cent.

The proportion of flesh shows a tendency at least to follow the plane of feeding, the high plane giving a high proportion, 41.16 per cent, and the low plane a low proportion of flesh, 36.51, with an intermediate value of 38.90 for the medium-plane calves. One calf from the low plane group, 568B, gave the lowest proportion, 29.54 per cent, while the three other low-plane calves gave results which compare very closely with the medium-fed calves. The foregoing data also shows that the more thrifty the calf—generally shown by his weight at birth—the higher the proportion of flesh obtained. Calf 568B, the weakest calf and also lowest in weight, gave the lowest proportion of flesh to live weight, 29.54 per cent. Calves 562B, 562C, and 564C, three of the heaviest calves, gave the highest proportion of flesh, or 41.53, 41.65 and 41.59 per cent, respectively. The heaviest calf, 563A, was an exception, giving but 36.66 per cent of flesh. Of the two Jersey calves, the most vigorous one, 11B, gave 40.28 per cent, while the weaker and lighter calf, 22A, gave but 36.36 per cent.

By studying the average percentage for each group we find no definite variation in the weights of the separated internal organs due to the plane of feeding of the mother. It may be noted that the weight of the nervous system (brain and spinal cord) of the two lighter calves, 568B and 567B, is rather higher in proportion to the live weight than for the heavier calves. It would thus appear that the development of the nervous system proceeds normally under all the conditions present in this experiment, regardless of how other parts of the animal may be affected by these conditions.

For the total of internal organs, Calf 566B of the low-plane group has the lowest proportion, 10.24 per cent, and Calf 568B of the same group has the highest proportion, 13.55 per cent. The other calves show intermediate values in the proportion of internal organs. The heavier and more thrifty animals, calves 562B, 562C, 565A, 563A and 566B, show low proportionate weights of internal organs, 10.84, 10.94, 10.81, 10.75, and 10.24 per cent respectively; while 568B, the lightest of the Herefords, give the largest proportion of internal organs, or 13.55 per cent. It will also be noticed that the heaviest Jersey calf, 11B, gives the lowest proportion of internal organs. As we pass from high plane to low plane the proportion of total internal organs to live weight increases—

10.89, 11.61, and 11.76 per cent. It thus appears that the internal organs tend to develop to normal weight under all the conditions of this experiment, and that other parts such as flesh respond directly to these conditions, causing the variation in the live weight at birth and the change in the percentage of the internal organs.

The percentage of composite skeleton to live weight does not show much variation between the high-plane and the medium-plane calves. The tendency, however, seems to be the same as shown by the total internal organs, the same explanation applying. All these values vary from 23.11 per cent to 29.35 per cent. For the four low-plane calves the proportion of skeleton is rather higher, none being below 29.10, and averaging 29.60 per cent for the group. It will also be observed that the more thrifty Jersey calf, 11B, shows a lower proportion of skeleton than the weaker Jersey calf, 22A.

It thus appears that the plane of nutrition to which the mother cow is subjected during pregnancy does not influence the proportionate weight of all parts of the animal in any regular way. It does appear, however, that the proportionate weight of some parts is influenced by the degree of thriftiness of the calf itself which in a general way is indicated by the live weight at birth. The degree of thriftiness of the calf may or may not be influenced by the plane of feeding of the mother. The plane of nutrition will certainly influence the condition of the mother, but may not affect the developing calf. However, it is evident from our data of live weights and proportion of composite flesh that a higher proportion of thriftiness is found in the better-fed than in the scant-fed group.

	High Plane	Medium Plane	Low Plane
Average live weight.....	82.53 pounds	80.87 pounds	66.20 pounds
Average percentage of flesh....	41.16	38.90	36.51

Considering now the individual calves, the most thrifty as judged from the live weight was Calf 563A, the mother being on a medium plane of nutrition. The weakest calf, 568B, was from the low-plane group of heifers, but the other calves of the same group compare very favorably in thriftiness with those of the medium-fed group. This is especially true for calf 566B whose live weight is practically equal to that of the heaviest calf produced in the experiment. The calves from the high-plane group have a live weight intermediate in value between the heaviest and lightest of the medium-plane calves. As shown above, the difference in thriftiness between the high-plane and medium-plane calves is not as

great as between the medium-and low-plane calves. The principal difference will be found to exist in the proportion of flesh and particularly of the fat in the animal.

CHEMICAL COMPOSITION

The chemical composition of the parts and of the total animal for each calf is shown in Tables 13 to 29, inclusive.

COMPOSITION OF ENTIRE ANIMAL

The figures for the composition of the entire animal are gathered together in Table 29. Some significant differences are seen on studying an average composition of the different groups.

The young organism shows a high percentage of moisture, which value decreases as growth proceeds. The Jersey fetus at 185 days showed 84.80 per cent moisture; at 232 days, 78.70 per cent; and just before birth, 74.19 per cent. The two normal Jersey

TABLE 13.—COMPOSITION OF THE SEPARATED PARTS OF THE JERSEY CALF 11B, STRANGLED AT BIRTH

	Fresh weight of sample	Mois- ture %	Fat %	Nitro- gen %	Ash %	Phos- phorus %
Blood, serum and water	1,675.0	90.847	0.190	1.424	0.427	0.094
Liver	581.0	83.877	1.074	2.245	0.957	0.135
Nervous system	338.0	79.915	7.333	1.668	1.234	0.278
Internal organs	3,167.0	79.571	5.790	2.199	0.902	0.144
Hair and hide	3,896.0	69.121	0.765	5.070	0.787	0.068
Skeleton (includes teeth and hoofs)	7,554.0	62.858	2.920	3.020	14.639	2.564
Flesh (includes right kidney fat)	12,862.0	77.818	4.416	2.702	0.904	0.163
Left kidney fat (special)	100.0	25.644	69.166	0.775	.....¹	.....¹
Excreta	301.0	61.158	8.417	2.779	1.426	0.025
Total animal as analyzed	30,374.0	73.857	3.494	2.942	4.288	0.738

¹Not determined.

TABLE 14.—COMPOSITION OF THE SEPARATED PARTS OF THE NEW BORN JERSEY CALF 22A FROM IMMATURE DAM

	Fresh weight of sample	Mois- ture %	Fat %	Nitro- gen %	Ash %	Phos- phorus %
Blood	1,015.8	84.432	.....¹	2.364	0.535	0.038
Hair and hide	2,224.0	63.284	0.673	5.238	1.020	0.087
Internal organs	3,299.0	78.324	4.729	2.304	1.069	0.237
Flesh	8,610.0	77.046	1.824	3.675	1.043	0.200
Skeleton	6,406.0	63.118	1.444	3.408	13.016	2.294
Kidney fat (special)	59.0	33.950	58.588	1.090	.....¹	.....¹
Total animal as analyzed	21,554.8	72.030	1.951	3.485	4.579	0.809

¹Not determined.

calves killed soon after birth showed 72.27 per cent and 73.85 per cent moisture, or an average value of 73.44 per cent moisture, if we include the calf just before birth. In the calves of low weight and vigor the percentage of moisture is higher, this condition being analogous to the under-development of the calf before birth. This is shown by Jersey Calf 85A, weighing 13.6 kilos, and giving a moisture content of 75.06 per cent, and by Hereford Calf 568B, weighing 17.7 kilos and giving a moisture content of 75.81 per cent.

TABLE 15.—COMPOSITION OF SEPARATED PARTS OF THE NEW BORN JERSEY CALF 85A FROM DAM ON A DEFICIENT MINERAL RATION

	Fresh weight of sample	Mois- ture %	Fat %	Nitro- gen %	Ash %	Phos- phorus %
Composite of calf after bleeding	12,105.2	74.608	4.190	2.566	4.430	0.795
Blood of calf	555.0	84.937	.....¹	2.291	0.782	0.025
Total calf as analyzed	12,660.2	75.061	4.006	2.554	4.270	0.761

¹Not determined.

TABLE 16.—COMPOSITION OF SEPARATED PARTS OF NEW-BORN HEREFORD CALF 560B (STRANGLER AT BIRTH) FROM DAM ON HIGH PLANE OF NUTRITION

	Fresh weight of sample	Mois- ture %	Fat %	Nitro- gen %	Ash %	Phos- phorus %
Composite of blood, organs, and flesh	25,943.0	77.549	4.791	2.826	0.898	0.149
Composite of bones, teeth, hoofs	9,252.0	62.028	2.743	.....¹	14.297	2.457
Composite of hair and hide	4,590.0	65.519	0.585	5.064	0.807	0.065
Excreta	1,019.0	.....¹	.....¹	.....¹	0.370	.....¹
Total animal as analyzed	39,785.0	72.552	3.829	.....¹	4.003	0.676

¹Not determined.

TABLE 17.—COMPOSITION OF SEPARATED PARTS OF NEW-BORN HEREFORD CALF 562B FROM DAM ON A HIGH PLANE OF NUTRITION

	Fresh weight of sample	Mois- ture %	Fat %	Nitro- gen %	Ash %	Phos- phorus %
Blood	1,746.4	81.065	.....²	2.878	0.684	0.031
Hair and hide	4,620.9	66.452	1.186	5.252	2.178	0.067
Composite flesh	15,518.4	75.513	4.544	2.976	1.060	0.167
Composite internal organs	4,051.1	76.225	7.668	2.158	1.227	0.203
Composite skeleton ...	9,854.2	66.422	3.731	2.798	12.365	2.137
Excreta	402.6	69.871	4.539	2.070	1.411	0.032
Kidney fat (special) .....	.....¹	37.642	53.736	1.251	0.699	0.087
Lean (special) .....	.....¹	75.976	1.091	3.232	1.200	0.186
Total animal as analyzed	36,193.6	72.166	4.024	3.112	4.285	0.686

¹Weight included in other samples.

²Not determined.

The percentage of moisture in the other calves, which may be considered of about average weight and vigor, is much the same for all. The values range from 71.56 per cent to 74.05 per cent and in-

TABLE 18.—COMPOSITION OF SEPARATED PARTS OF FULL TERM HEREFORD CALF 560D, OBTAINED BY POST MORTEM FROM DAM ON HIGH PLANE OF NUTRITION

	Fresh weight of sample	Mois-ture %	Fat %	Nitro-gen %	Ash %	Phos-phorus %
Hair and hide	4,130.5	65.833	1.240	5.426	0.946	0.090
Composite flesh (contains some blood)	13,120.1	76.608	4.073	2.799	0.910	0.163
Composite internal organs (contains most of the blood)	5,137.0	80.911	5.132	2.056	0.997	0.161
Composite skeleton	8,660.7	61.925	4.691	3.115	13.745	3.215
Excreta	532.9	72.218	4.712	2.166	1.180	0.130
Kidney fat (both sides)	218.3	38.561	54.676	1.091	0.505	0.091
Total animal as analyzed	31,799.5	71.569	4.402	3.084	4.426	0.983

TABLE 19.—COMPOSITION OF SEPARATED PARTS OF NEW-BORN HEREFORD CALF 562C FROM DAM ON A HIGH PLANE OF NUTRITION

	Fresh weight of sample	Mois-ture %	Fat %	Nitro-gen %	Ash %	Phos-phorus %
Blood	1,777.5	82.351	.....²	2.587	0.839	0.028
Hair and hide	4,323.3	67.297	1.737	5.106	0.973	0.065
Composite flesh	16,578.7	76.813	4.626	2.598	0.983	0.172
Composite internal organs	4,354.5	77.026	7.449	2.055	1.090	0.210
Composite skeleton	11,682.8	66.953	4.724	2.731	10.823	2.607
Excreta	782.4	91.480	0.701	0.654	0.848	0.028
Marrow (special) .....	.....¹	64.709	27.402	1.081	0.986	0.122
Kidney fat (special)	232.5	33.088	59.859	0.922	0.479	0.078
Lean special .....	.....¹	78.473	1.285	2.762	1.071	0.203
Total animal as analyzed	39,499.2	73.419	4.364	2.813	3.395	0.875

¹Weight included in other samples.

²Not determined.

TABLE 20.—COMPOSITION OF SEPARATED PARTS OF NEW-BORN HEREFORD CALF 565A FROM DAM ON A MEDIUM PLANE OF NUTRITION

	Fresh weight of sample	Mois-ture %	Fat %	Nitro-gen %	Ash %	Phos-phorus %
Blood	1,805.3	83.202	0.019	2.593	0.474	0.035
Hair and hide	4,990.0	69.770	1.395	4.850	1.467	0.065
Composite flesh	16,556.0	77.283	3.779	2.656	0.915	0.169
Composite internal organs	4,388.0	77.915	6.781	2.035	1.069	0.208
Composite skeleton	11,156.0	65.311	2.299	2.589	13.755	2.452
Excreta	709.0	77.989	3.136	1.542	0.974	0.018
Marrow (special) .....	.....¹	76.713	15.037	0.949	.....²	.....²
Total animal as analyzed	39,604.3	73.317	3.212	2.822	4.599	0.794

¹Weight included in other samples.

²Not determined.

clude four Herefords from the high plane, five Herefords from the medium plane, and three Herefords from the low plane, and three Jersey calves the mothers of which may be considered to have been upon a medium plane of nutrition. The average value for all the Herefords is 72.80 per cent and for the three normal Jerseys is 73.44 per cent. While the relation between moisture content and the plane of nutrition of the animal is not exact, consideration of the average result for each group shows the tendency of the moisture content to rise as we pass from high to low plane of nutrition.

The percentage of fat shows the lowest value, 2.36, in the youngest Jersey fetus of 185 days and increases as the time of birth approaches. For the new-born Jersey calves the values range from 3.49 to 4.59 per cent. Jersey Calf 22A is a notable exception, giving a percentage value of fat in the entire animal of a little

TABLE 21.—COMPOSITION OF SEPARATED PARTS OF NEW-BORN HEREFORD CALF 563A FROM DAM ON A MEDIUM PLANE OF NUTRITION

	Fresh weight of sample	Mois- ture %	Fat %	Nitro- gen %	Ash %	Phos- phorus %
Blood	1,958.6	79.790	0.053	3.096	0.474	0.021
Hair and hide	5,848.0	72.179	0.550	3.920	3.269	0.062
Composite flesh	14,906.0	76.020	4.258	2.797	1.002	0.156
Composite internal or- gans	4,372.0	76.105	8.157	2.083	1.123	0.177
Composite skeleton	10,804.0	66.316	4.345	2.776	11.632	2.119
Excreta	641.0	73.793	5.075	1.762	1.179	0.034
Marrow (special)	70.732	21.836	1.003	.....¹	.....²	.....²
Kidney fat (special)	29.546	64.293	0.873	0.425	0.425	0.076
Total animal as analyzed	38,529.6	72.880	3.959	2.878	4.317	0.685

¹Weight included in other samples.

²Not determined.

TABLE 22.—COMPOSITION OF SEPARATED PARTS OF NEW-BORN HEREFORD CALF 564B FROM DAM ON A MEDIUM PLANE OF NUTRITION

	Fresh weight of sample	Mois- ture %	Fat %	Nitro- gen %	Ash %	Phos- phorus %
Blood	1,862.0	82.024	.....¹	2.725	0.598	0.029
Hair and hide	3,720.0	65.876	0.787	5.161	1.116	0.060
Composite flesh	11,032.0	76.730	3.998	2.809	0.949	0.171
Composite internal or- gans	4,117.0	77.925	5.864	2.141	1.057	0.206
Composite skeleton	8,054.0	63.856	3.106	3.037	13.919	2.528
Excreta	326.0	75.524	3.508	2.241	0.991	0.062
Kidney fat (special)	53.526	39.645	1.179	0.616	0.616	0.091
Total animal as analyzed	29,111.0	72.275	3.344	3.066	4.552	0.804

¹Weight included in other samples.

²Not determined.

less than 2 per cent. This result appears abnormal and may best be disregarded in seeking the normal tendency. The percentage of fat in the Hereford calves shows some relation to the plane of nutrition considered as a whole, especially if average results are considered. One high-plane calf gives the highest results, 4.40 per cent, the average result for fat for all four calves of the high-plane group being 4.15 per cent. Two calves in the medium-fed group, 563A and 565B, give respectively 3.96 and 3.94, which closely follow the average for the high-plane group. One calf of the medium-fed group shows the lowest result for all of the Herefords, or 3.21 per cent. The average result for the five medium-plane Herefords is 3.56 per cent. Calf 566B, the heaviest calf of the low-plane group, gives a lower per cent of fat than Calf 568B,

TABLE 23.—COMPOSITION OF SEPARATED PARTS OF NEW-BORN HEREFORD CALF 565B FROM DAM ON A MEDIUM PLANE OF NUTRITION

	Fresh weight of sample	Moisture %	Fat %	Nitrogen %	Ash %	Phosphorus %
Blood	1,672.6	81.961	.....³	2.830	0.687	0.035
Hair and hide	4,019.9	63.822	0.874	5.403	2.228	0.093
Composite flesh	13,016.3	76.133	4.684	2.773	1.040	0.178
Composite internal organs	3,586.2	76.981	6.885	2.188	1.159	0.223
Composite skeleton	8,708.9	65.122	3.786	2.804	13.046	2.414
Excreta ¹	479.1	.....	.....	.....	.....	.....
Kidney fat (special) .....	.....²	28.864	61.917	1.362	0.605	0.121
Lean (special) .....	.....²	78.067	1.352	2.924	1.108	0.222
Total animal as analyzed	31,003.9	71.864	3.940	3.058	4.561	0.793

¹Not analyzed.

²Weight included in other samples.

³Not determined.

TABLE 24.—COMPOSITION OF THE SEPARATED PARTS OF THE NEW-BORN HEREFORD CALF 564C FROM DAM ON A MEDIUM PLANE OF NUTRITION

	Fresh weight of sample	Moisture %	Fat %	Nitrogen %	Ash %	Phosphorus %
Blood	2,044.0	79.394	.....³	3.150	0.740	0.029
Hair and hide	4,031.3	66.684	0.930	5.245	0.914	0.059
Composite flesh	16,034.4	76.418	3.637	2.792	1.032	0.184
Composite internal organs	4,691.8	77.591	6.215	2.184	1.120	0.218
Composite skeleton	10,636.7	64.183	3.243	3.022	13.569	3.045
Excreta	479.1	71.727	5.587	1.801	1.194	0.068
Marrow (special) .....	.....¹	72.508	1.775	1.446	.....	.....
Kidney fat (special) .....	.....¹	30.992	62.067	1.037	0.599	0.088
Lean special .....	.....¹	77.802	0.820	2.963	1.153	0.222
Total animal as analyzed	37,917.3	72.197	3.386	3.049	4.534	0.967

¹Weight included in other samples.

²Not determined.

the lightest and least vigorous calf of the same group. If we average all four of the low-plane values for fat we obtain 3.24 per cent. Thus we see that the tendency of the results for fat in the Hereford calves is to increase from the low plane to the higher planes of nutrition.

The per cents of nitrogen, ash, and phosphorus are all lowest in the youngest fetus (185 days) and increase in value as the time of birth approaches. Of the Jersey calves at birth the results for nitrogen vary from 2.55 to 2.95 per cent, with the exception of Jersey Calf 22A which has an unusually high value, 3.48 per cent. The ash percentage varies from 4.09 to 4.57 per cent, while the phosphorus percentage varies from 0.617 to 0.809 per cent, the extreme values for ash associating with the extreme values for phosphorus.

With the Hereford calves the percentage of nitrogen in most

TABLE 25.—COMPOSITION OF THE SEPARATED PARTS OF THE NEW-BORN HEREFORD CALF 568B FROM DAM ON A LOW PLANE OF NUTRITION

	Fresh weight of sample	Moisture %	Fat %	Nitrogen %	Ash %	Phosphorus %
Blood	912.0	86.842	.....¹	1.950	0.419	0.026
Hair and hide	2,477.0	74.622	0.895	3.832	1.333	0.073
Composite flesh	5,226.0	79.413	4.242	2.176	0.858	0.140
Composite internal organs	2,397.0	78.327	8.294	1.868	0.951	0.164
Composite skeleton	5,148.0	69.636	2.293	2.736	10.861	1.937
Excreta	280.0	75.279	2.408	1.866	1.020	0.040
Kidney fat (special) ....	.....¹	31.659	64.260	0.809	0.386	0.091
Total animal as analyzed	16,440.0	75.813	3.452	2.538	4.054	0.688

¹Weight included in other samples.

²Not determined.

TABLE 26.—COMPOSITION OF THE SEPARATED PARTS OF THE NEW-BORN HEREFORD CALF 567B FROM DAM ON A LOW PLANE OF NUTRITION

	Fresh weight of sample	Moisture %	Fat %	Nitrogen %	Ash %	Phosphorus %
Blood	1,335.4	83.016	.....²	2.558	0.782	0.027
Hair and hide	3,415.5	66.707	0.442	5.115	2.623	0.077
Composite flesh	11,124.3	77.197	3.903	2.639	1.075	0.173
Composite internal organs	3,183.6	77.522	6.433	2.180	1.236	0.230
Composite skeleton	8,513.3	65.738	2.834	2.770	13.339	2.403
Excreta	584.0	78.089	3.055	1.619	1.025	0.019
Marrow (special) .....	.....¹	79.786	1.129	1.183	0.939	0.115
Kidney fat (special) ....	.....¹	25.392	67.572	0.935	0.541	0.089
Lean (special) .....	.....¹	79.165	0.745	2.693	1.069	0.205
Total animal as analyzed	28,156.1	72.792	3.243	2.902	4.974	0.832

¹Weight included in other samples.

²Not determined.

cases vary but little from the average value which is 2.92 per cent. But in some few cases the variation from the average is 7 to 14 per cent of the average. Calf 568B shows the greatest variation in this value, which is 0.4 per cent less. Considered by groups the high plane shows the highest per cent, 3.00; followed by the medium-plane result, 2.97, and lastly by the low-plane result, or 2.80. Thus it appears that the nitrogen shows a decreasing value the lower the plane of feeding to which the mother of the calf had been subjected, and in spite of a lower proportion of fat.

The ash and the phosphorus show a slight tendency to increase in percentage value as we pass from the high to the low plane of feeding. The values for ash are: high plane, 4.15 per

TABLE 27.—COMPOSITION OF THE SEPARATED PARTS OF THE NEW-BORN HEREFORD CALF 568B FROM DAM ON A LOW PLANE OF NUTRITION

	Fresh weight of sample	Mois- ture %	Fat %	Nitro- gen %	Ash %	Phos- phorus %
Blood	2,104.9	82.948	.....²	2.517	0.684	0.032
Hair and hide	4,856.2	70.114	0.772	4.540	1.063	0.061
Composite flesh	15,750.9	80.110	2.351	2.740	1.024	0.146
Composite internal or- gans	4,133.4	79.248	5.463	2.111	1.060	0.213
Composite skeleton	12,224.3	64.468	2.934	2.602	15.469	3.081
Excreta	280.7	77.092	2.960	1.656	1.058	0.121
Marrow (special) .....	.....¹	62.280	29.641	0.967	.....²	.....²
Kidney fat (special) ....	.....¹	45.295	47.180	0.975	0.602	0.095
Lean (special) .....	.....¹	79.933	0.704	2.677	1.062	0.178
Total animal as analyzed	39,350.4	74.057	2.543	2.834	5.502	1.048

¹Weight included in other samples.

²Not determined.

TABLE 28.—COMPOSITION OF THE SEPARATED PARTS OF THE NEW-BORN HEREFORD CALF 568C FROM DAM ON A LOW PLANE OF NUTRITION

	Fresh weight of sample	Mois- ture %	Fat %	Nitro- gen %	Ash %	Phos- phorus %
Blood	1,451.5	83.547	.....²	2.552	0.813	0.024
Hair and hide	3,657.1	67.455	1.027	5.190	0.888	0.060
Composite flesh	12,898.9	76.134	3.984	2.728	1.015	0.179
Composite internal or- gans	4,048.3	78.866	5.847	1.959	1.041	0.198
Composite skeleton	9,786.2	61.874	4.049	3.001	14.621	3.277
Excreta	671.9	78.721	4.193	1.386	1.027	0.077
Marrow (special) .....	.....¹	71.343	21.441	0.945	2.940	0.113
Kidney fat (special) ....	.....¹	20.866	74.029	0.553	0.387	0.086
Lean (special) .....	.....¹	78.419	0.657	2.758	1.101	0.207
Total animal as analyzed	32,513.9	71.590	3.729	2.956	5.090	1.091

¹Weight included in other samples.

²Not determined.

cent; medium plane, 4.51 per cent; and for low plane, 4.90 per cent. In general the values for phosphorus follow directly the per cent of ash.

COMPOSITION OF THE SEPARATED PARTS.

Tables 13 to 28, inclusive, show the composition of each individual calf analyzed; as a whole and by parts. For convenience of study these data are regrouped under the divisions of the animal in tables 30 to 36, inclusive. Inspection of the data under each division shows that these parts vary in composition in much the same manner as does the composition of the entire animal.

Blood.—In the blood (Table 30) we find the highest percentage of moisture in Calf 568B and Calf 22A, which were the calves of

TABLE 29.—THE COMPOSITION OF ENTIRE BOVINE FETUS AND CALVES

	Moisture %	Fat %	Nitrogen %	Ash %	Phosphorus %
Jersey fetus (185 days) 43X	84.801	2.363	1.673	1.776	0.283
Jersey fetus (232 days) 13X	78.700	2.573	2.011	3.180	0.370
Jersey fetus (279 days) 2X	74.192	3.384	2.735	4.062	0.688
Jersey Calf 11A	72.276	4.591	2.956	4.096	0.617
Jersey Calf 11B	73.857	3.494	2.942	4.288	0.738
Jersey Calf 22A ¹ subnormal	72.030	1.951	3.485	4.579	0.809
Jersey Calf 85A ¹ abnormal	75.061	4.006	2.554	4.270	0.761
Average for Jersey Calves at birth (2X, 11B, 11A)	73.442	3.823	2.878	4.149	0.681
Hereford Calf 560B	72.552	3.829	....²	4.003	0.676
Hereford Calf 562B	72.166	4.024	3.112	4.285	0.686
Hereford Calf 560D	71.569	4.402	3.084	4.426	0.983
Hereford Calf 562C	73.419	4.364	2.813	3.895	0.875
Average for Herefords (high plane)	72.427	4.155	3.003	4.152	0.805
Hereford Calf 565A	73.317	3.212	2.822	4.599	0.794
Hereford Calf 563A	72.880	3.959	2.878	4.317	0.685
Hereford Calf 564B	72.275	3.344	3.066	4.552	0.804
Hereford Calf 565B	71.864	3.940	3.058	4.561	0.793
Hereford Calf 564C	72.197	3.386	3.049	4.534	0.967
Average for Herefords (medium plane)	72.507	3.568	2.975	4.513	0.809
Hereford Calf 568B	75.813	3.452	2.538	4.054	0.688
Hereford Calf 567B	72.792	3.243	2.902	4.974	0.832
Hereford Calf 566B	74.057	2.543	2.834	5.502	1.048
Hereford Calf 568C	71.590	3.729	2.956	5.090	1.091
Average for Herefords (low plane)	73.563	3.242	2.808	4.905	0.915
Average for all Herefords	72.807	3.648	2.926	4.523	0.841

¹Omitted from averages.

²Not determined.

lowest weight and vigor. The heaviest calf, 563A, shows, with one exception, the lowest percentage of moisture in the blood. The animals from the low plane of nutrition show a higher percentage of moisture in the blood than those from the higher plane of nutrition. A difference between the high and medium-plane groups is not apparent from our data. The true percentage of moisture in the blood of Jersey Calf 11B is not shown by the result, 90.84, as this blood sample had been mingled with water and other body liquids before it was obtained for analysis. The nitrogen, ash, and phosphorus in the blood vary inversely as the percentage of moisture.

Hair and Hide.—The percentage of moisture in the hair and hide (Table 31) varies for the individual without regard to the plane of nutrition. The heaviest and lightest calves, 563A and

TABLE 30.—COMPOSITION OF THE BLOOD OF THE JERSEY AND HEREFORD CALVES AT BIRTH

Calves Analyzed	Moisture %	Fat %	Nitrogen %	Ash %	Phosphorus %
Jersey Calf 11B	90.847 ¹	0.190	1.424	0.427	0.024
Jersey Calf 22A	84.432	.....	2.364	0.535	0.038
Average for Jersey calves .....	.....	.....	1.894	0.481	0.031
Hereford Calf 560B ² .....	.....	.....	.....	.....	.....
Hereford Calf 562B	81.065	.....	2.878	0.684	0.031
Hereford Calf 560D ³ .....	.....	.....	.....	.....	.....
Hereford Calf 562C	82.351	.....	2.587	0.839	0.028
Average for Herefords (high plane)	81.708	.....	2.733	0.762	0.030
Hereford Calf 565A	83.202	0.019	2.593	0.474	0.035
Hereford Calf 563A	79.790	0.053	3.096	0.474	0.021
Hereford Calf 564B	82.024	.....	2.725	0.598	0.029
Hereford Calf 565B	81.961	.....	2.830	0.687	0.035
Hereford Calf 564C	79.394	.....	3.150	0.740	0.029
Average for Herefords (medium plane)	81.274	.....	2.879	0.595	0.030
Hereford Calf 568B	86.842	.....	1.950	0.419	0.026
Hereford Calf 567B	83.016	.....	2.558	0.782	0.027
Hereford Calf 566B	82.948	.....	2.517	0.684	0.032
Hereford Calf 568C	83.547	.....	2.552	0.813	0.024
Average for Herefords (low plane)	84.088	.....	2.394	0.675	0.027
Average for all Herefords	82.376	.....	2.676	0.654	0.029

¹Omitted from averages. Sample mixed with water.

²Blood not obtained as separate sample.

³No determination of ether extract made.

568B, show the highest percentage of moisture, while other calves, both Jerseys and Herefords, of average weight and vigor show values ranging from 63 to 69 per cent. However, if average results for each group be considered, the tendency to increase in moisture content as we pass from high to low plane becomes apparent.

The percentage of fat in the hair and hide vary within rather wide limits even within the same group. The value found depends largely upon the care with which the hide is separated from sub-dermal tissue. There is generally more or less fat lying between this sub-dermal tissue and the hide, and unless great care is taken considerable quantities of this will cling to the hide on removal. The group averages show a decrease with a lower plane of nutrition.

The most striking fact in the composition of the hair and hide

TABLE 31.—COMPOSITION OF THE HAIR AND HIDE OF THE JERSEY AND HEREFORD CALVES AT BIRTH

Calves Analyzed ¹	Mois- ture %	Fat %	Nitro- gen %	Ash %	Phos- phorus %
Jersey Calf 11B	69.121	0.765	5.070	0.787	0.068
Jersey Calf 22A	63.284	0.673	5.238	1.020	0.087
Average for Jersey calves	66.202	0.719	5.154	0.903	0.078
Hereford Calf 560B	65.519	0.585	5.064	0.807	0.065
Hereford Calf 562B	66.452	1.186	5.252	2.178 ¹	0.067
Hereford Calf 560D	65.833	1.240	5.426	0.946	0.090
Hereford Calf 562C	67.297	1.737	5.106	0.973	0.065
Average for Herefords (high plane)	66.275	1.583	5.212	0.909	0.072
Hereford Calf 565A	69.770	1.395	4.850	1.467	0.065
Hereford Calf 563A	72.179	0.550	3.920	3.269 ¹	0.062
Hereford Calf 564B	65.876	0.787	5.161	1.116	0.060
Hereford Calf 565B	63.822	0.874	5.403	2.228 ¹	0.093
Hereford Calf 564C	66.684	0.930	5.245	0.914	0.059
Average for Herefords (medium plane)	67.666	0.907	4.916	1.166	0.068
Hereford Calf 568B	74.622	0.895	3.832	1.333	0.073
Hereford Calf 567B	66.707	0.442	5.115	2.623 ¹	0.077
Hereford Calf 566B	70.114	0.772	4.540	1.063	0.061
Hereford Calf 568C	67.455	1.027	5.190	0.888	0.060
Average for Herefords (low plane)	69.725	0.784	4.669	1.095	0.068
Average for all Herefords	67.871	0.955	4.931	1.056	0.069

¹Omitted from averages. Samples contaminated by some dirt.

is the high percentage of nitrogen it contains. This seems to vary in the way we have observed in the entire animal, that is, falling in percentage value as we pass from the high-plane to the low-plane animals. It will be noticed that the percentage of ash in the hair and hide is very high in four cases. This is due to the fact that the hide was contaminated with dirt which could not be removed by washing. It will be noted that the per cent of phosphorus is not higher in those cases where the ash is high, which would indicate that the additional ash is extraneous dirt. The true ash percentages are probably 0.7 per cent to 1.2 per cent. The four high results were omitted in the calculation of averages.

Flesh.—The percentage of moisture in the flesh (Table 32) does not show wide variation but shows the same trend as the moisture in the entire animal. Calf 562B from the high-plane group

TABLE 32.—COMPOSITION OF THE COMPOSITE FLESH OF THE JERSEY AND HEREFORD CALVES AT BIRTH

Calves Analyzed	Moisture %	Fat %	Nitrogen %	Ash %	Phosphorus %
Jersey Calf 11B	77.818	4.416	2.702	0.904	0.163
Jersey Calf 22A	77.046	1.824	3.675	1.043	0.200
Average for Jersey calves	77.432	3.120	3.189	0.974	0.182
Hereford Calf 560B ¹ .....	.....	.....	.....	.....	.....
Hereford Calf 562B	75.513	4.544	2.976	1.060	0.167
Hereford Calf 560D	76.608	4.073	2.799	0.910	0.163
Hereford Calf 562C	76.813	4.626	2.598	0.983	0.172
Average for Herefords (high plane)	76.311	4.414	2.791	0.984	0.167
Hereford Calf 565A	77.283	3.779	2.656	0.915	0.169
Hereford Calf 563A	76.020	4.258	2.797	1.002	0.156
Hereford Calf 564B	76.730	3.998	2.809	0.949	0.171
Hereford Calf 565B	76.133	4.684	2.773	1.040	0.178
Hereford Calf 564C	76.418	3.637	2.792	1.032	0.184
Average for Herefords (medium plane)	76.517	4.071	2.765	0.988	0.172
Hereford Calf 568B	79.413	4.242	2.176	0.858	0.140
Hereford Calf 567B	77.197	3.903	2.639	1.075	0.173
Hereford Calf 566B	80.110	2.351	2.740	1.024	0.146
Hereford Calf 568C	76.134	3.984	2.728	1.015	0.179
Average for Herefords (low plane)	78.214	3.620	2.571	0.993	0.160
Average for all Herefords	77.031	4.007	2.707	0.989	0.167

¹Flesh not obtained as a separate sample.

shows the lowest percentage of moisture and Calf 566B in the low-plane group, the highest percentage of moisture. The average value for moisture in the flesh of the five medium-plane calves is 76.51 per cent, and for the four low-plane calves, 78.21 per cent.

The percentage of fat in the flesh of the Hereford varies from 2.35 to 4.68 per cent without regard to the plane of nutrition. The heaviest and lightest of these calves had the same percentage of fat in the flesh, 4.25 per cent and 4.24 per cent. Jersey Calf 22A has an exceptionally low value, 1.82 per cent. If we consider the average value for each group of Herefords we see at once the tendency of the value for fat to fall as we pass from high to low plane. The tendency of nitrogen is to decrease in percentage value

TABLE 33.—COMPOSITION OF THE COMPOSITE INTERNAL ORGANS OF THE JERSEY AND HEREFORD CALVES AT BIRTH

Calves Analyzed	Moisture %	Fat %	Nitrogen %	Ash %	Phosphorus %
Jersey Calf 11B	80.212 ¹	5.247	2.162	0.937	0.154
Jersey Calf 22A	78.324	4.729	2.304	1.069	0.237
Average for Jersey calves	78.324	4.988 ²	2.233	1.003	0.196
Hereford Calf 560B ³ .....	.....	.....	.....	.....	.....
Hereford Calf 562B	76.225	7.668	2.158	1.227	0.203
Hereford Calf 560D	80.911 ¹	5.132 ¹	2.056	0.997	0.161
Hereford Calf 562C	77.026	7.449	2.055	1.090	0.210
Average for Herefords (high plane)	76.625	7.559	2.090	1.105	0.191
Hereford Calf 565A	77.915	6.781	2.035	1.069	0.208
Hereford Calf 563A	76.105	8.157	2.083	1.123	0.177
Hereford Calf 564B	77.925	5.864	2.141	1.057	0.206
Hereford Calf 565B	76.981	6.885	2.188	1.159	0.223
Hereford Calf 564C	77.591	6.215	2.184	1.120	0.218
Average for Herefords (medium plane)	77.303	6.780	2.126	1.106	0.206
Hereford Calf 568B	78.327	8.294	1.868	0.951	0.164
Hereford Calf 567B	77.522	6.433	2.180	1.236	0.230
Hereford Calf 566B	79.248	5.463	2.111	1.060	0.213
Hereford Calf 568C	78.866	5.847	1.959	1.041	0.198
Average for Herefords (low plane)	78.491	6.509	2.029	1.072	0.201
Average for all Herefords	77.887	6.682	2.085	1.094	0.201

¹Omitted from averages. Samples contained much blood.

²Internal organs not obtained as a separate sample.

³Result not of value as an average. Neither calf gives a typical per cent for fat in internal organs.

from high to low plane of nutrition. The ash and the phosphorus in the same interval, tend to remain quite constant. The results on composite flesh of Jersey Calf 22A are all more or less abnormal. Jersey Calf 11B gives results in close agreement with the Hereford calves.

Internal Organs.—The moisture in the internal organs (Table 33) tends to a higher percentage value in low-plane calves than in the others. The average value for the four low-plane calves is 78.49 per cent; for the five medium-plane calves, 77.30 per cent; and for two high-plane calves, 76.62 per cent. Calf 560D, obtained by post mortem, was not bled, therefore most of the blood was with the internal organs. This explains the abnormally high result for moisture and low result for fat in the internal organs of this calf. These results are not included in the calculated averages. Jersey

TABLE 34.—COMPOSITION OF THE COMPOSITE SKELETON OF THE JERSEY AND HEREFORD CALVES AT BIRTH

Calves Analyzed	Moisture %	Fat %	Nitrogen %	Ash %	Phosphorus %
Jersey Calf 11B	62.858	2.920	3.020	14.639	2.564
Jersey Calf 22A	63.118	1.444	3.408	13.016	2.294
Average for Jersey calves	62.988	2.182	3.214	13.828	2.429
Hereford Calf 560B	62.028	2.743	.....¹	14.297	2.457
Hereford Calf 562B	66.422	3.731	2.798	12.365	2.137
Hereford Calf 560D	61.925	4.691	3.115	13.745	3.215
Hereford Calf 562C	66.953	4.724	2.731	10.823	2.607
Average for Herefords (high plane)	64.332	3.972	2.881	12.808	2.604
Hereford Calf 565A	65.311	2.299	2.589	13.755	2.452
Hereford Calf 563A	66.316	4.345	2.776	11.632	2.119
Hereford Calf 564B	63.856	3.106	3.037	13.919	2.528
Hereford Calf 565B	65.122	3.786	2.804	13.046	2.414
Hereford Calf 564C	64.183	3.243	3.022	13.569	3.045
Average for Herefords (medium plane)	64.958	3.356	2.846	13.184	2.511
Hereford Calf 568B	69.636	2.293	2.736	10.861	1.937
Hereford Calf 567B	65.738	2.834	2.770	13.339	2.403
Hereford Calf 566B	64.468	2.934	2.602	15.469	3.081
Hereford Calf 568C	61.874	4.049	3.001	14.621	3.277
Average for Herefords (low plane)	65.429	3.028	2.777	13.570	2.675
Average for all Herefords	64.918	3.445	2.832	13.188	2.590

¹Not determined.

Calf 22A shows a low plane result, 78.32 per cent, while the high result for Jersey Calf 11B is due to the fact that this animal was not bled, therefore the internal organs contained considerable blood. The fat of the new born calves is mostly internal, which is demonstrated by the high percentage of fat found in the samples of internal organs. Again, Jersey Calf 22A shows an emaciated condition, having the lowest percentage of fat in the internal organs. The percentage of nitrogen in the internal organs is slightly but distinctly lower than in the flesh. The average of all results for per cent of nitrogen in the flesh of the Herefords is 2.71 per cent, while the average value for per cent of nitrogen in internal organs is 2.08 per cent. The per cent of ash and phosphorus in the internal organs tends to a higher value than in the flesh. The average per cents of ash and of phosphorus in the flesh are 0.989 and 0.167,

TABLE 35.—COMPOSITION OF THE EXCRETA OF THE JERSEY AND HEREFORD CALVES AT BIRTH

Calves Analyzed	Moisture %	Fat %	Nitrogen %	Ash %	Phosphorus %
Jersey Calf 11B	61.158	8.417	2.779	1.426	0.025
Jersey Calf 22A ¹ .....	.....	.....	.....	.....	.....
Average for Jersey calves .....	.....	.....	.....	.....	.....
Hereford Calf 560B ¹ .....	.....	.....	.....	.....	.....
Hereford Calf 562B	69.871	4.539	2.070	1.411	0.032
Hereford Calf 560D	72.218	4.712	2.166	1.180	0.130
Hereford Calf 562C	91.480	0.701	0.654	0.848	0.028
Average for Herefords (high plane)	77.856	3.317	1.630	1.146	0.063
Hereford Calf 565A	77.989	3.136	1.542	0.974	0.018
Hereford Calf 563A	73.793	5.075	1.762	1.179	0.034
Hereford Calf 564B	75.524	3.508	2.241	0.991	0.062
Hereford Calf 565B ¹ .....	.....	.....	.....	.....	.....
Hereford Calf 564C	71.727	5.587	1.801	1.194	0.068
Average for Herefords (medium plane)	74.758	4.326	1.836	1.085	0.046
Hereford Calf 568B	75.279	2.408	1.866	1.020	0.040
Hereford Calf 567B	78.089	3.055	1.619	1.025	0.019
Hereford Calf 566B	77.092	2.960	1.656	1.058	0.121
Hereford Calf 568C	78.721	4.193	1.386	1.027	0.077
Average for Herefords (low plane)	77.295	3.154	1.632	1.033	0.064
Average for all Herefords	76.526	3.625	1.706	1.083	0.057

¹Excreta not analyzed.

respectively; in the internal organs the values are 1.094 and 0.201 per cent, respectively. The plane of nutrition does not affect the values for nitrogen, ash and phosphorus in the internal organs with any regularity.

Skeleton.—For the composite skeleton (Table 34) we obtain no striking results for moisture, with the exception of Calf 568B, the lightest of all, which shows a high percentage of moisture, 69.63, as compared with values for the others which range from 62 to 66 per cent. Calf 22A shows an under-nourished condition as indicated in the comparatively low per cent of fat in the skeleton, 1.44. Of the Herefords the highest two results for fat are found in the high-plane group while the heaviest calf, 563A, of the medium-plane group also furnished a high result. The lowest re-

TABLE 36.—COMPOSITION OF THE KIDNEY FAT OF THE JERSEY AND HEREFORD CALVES AT BIRTH

Calves Analyzed	Moisture %	Fat %	Nitrogen %	Ash %	Phosphorus %
Jersey Calf 11B	25.644	69.166	0.775	.....¹	.....¹
Jersey Calf 22A	33.950	58.588	1.090	.....¹	.....¹
Average for Jersey calves	29.797	63.877	0.933	.....	.....
Hereford Calf 560B ¹ .....	.....	.....	.....	.....	.....
Hereford Calf 562B	37.642	53.736	1.251	0.699	0.087
Hereford Calf 560D	38.561	54.676	1.091	0.505	0.091
Hereford Calf 562C	33.088	59.859	0.922	0.479	0.078
Average for Herefords (high plane)	36.430	56.090	1.088	0.561	0.085
Hereford Calf 565A ¹ .....	.....	.....	.....	.....	.....
Hereford Calf 563A	29.546	64.293	0.873	0.425	0.076
Hereford Calf 564B	53.526 ²	39.645 ²	1.179	0.616	0.091
Hereford Calf 565B	28.864	61.917	1.362	0.605	0.121
Hereford Calf 564C	30.992	62.067	1.037	0.599	0.088
Average for Herefords (medium plane)	29.801	62.759	1.113	0.561	0.094
Hereford Calf 568B	31.659	64.260	0.809	0.386	0.091
Hereford Calf 567B	25.392	67.572	0.935	0.541	0.089
Hereford Calf 566B	45.295	47.180	0.975	0.602	0.095
Hereford Calf 568C	20.866	74.029	0.553	0.387	0.086
Average for Herefords (low plane)	30.803	63.260	0.818	0.479	0.090
Average for all Herefords	32.191	60.959	0.998	0.531	0.090

¹Kidney fat not analyzed.

²Omitted from averages.

³Not determined.

TABLE 37.—SUM OF THE PERCENTAGES OF MOISTURE AND FAT IN THE ENTIRE ANIMALS AND IN THE SEVERAL PARTS ANALYZED										
	Entire animal	Blood	Hair and hide	Compos- ite flesh	Compos- internal organs	Com- posite skeleton	Excreta	Kidney fat	Marrow	Lean flesh
Jersey fetus, 185 days 43X	87.164	.....	.....	.....	.....	.....	.....	.....	.....	.....
Jersey fetus, 232 days 13X	81.273	.....	.....	.....	.....	.....	.....	.....	.....	.....
Jersey fetus, 279 days 2X	77.576	.....	.....	.....	.....	.....	.....	.....	.....	.....
Jersey calf 11A	76.867	.....	.....	.....	.....	.....	.....	.....	.....	.....
Jersey calf 11B	77.351	90.847 ¹	69.886	82.234	85.459	65.778	69.575	.....	.....	.....
Jersey calf 22A, subnormal	73.981	84.432	63.957	78.870	83.053	64.562	.....	.....	.....	.....
Jersey calf 85A, abnormal	79.067	84.937	.....	.....	.....	.....	.....	.....	.....	.....
Average for Jersey calves 2X, 11A, 11B	77.265	.....	.....	.....	.....	.....	.....	.....	.....	.....
Hereford calf 560B	76.381	.....	66.104	.....	.....	64.771	.....	.....	.....	.....
Hereford calf 562B	76.190	81.065	67.638	80.057	83.893	70.153	74.410	91.378	.....	77.087
Hereford calf 560D	75.971	.....	67.073	80.681	86.043 ²	66.616	76.930	93.237	.....	.....
Hereford calf 562C	77.783	82.351	69.034	81.439	84.475	71.677	92.181	92.947	92.111	79.758
Average for Hereford calves, high plane	76.582	81.708	67.858	80.725	84.184	68.304	81.273	92.521	.....	78.413
Hereford calf 565A	76.529	83.202	71.165	81.062	84.696	67.610	81.125	.....	91.750	.....
Hereford calf 563A	76.839	79.790	72.729	80.278	84.262	70.661	78.878	93.839	92.568	.....
Hereford calf 564B	75.619	82.024	66.663	80.728	83.789	66.968	79.032	93.171	.....	.....
Hereford calf 565B	75.804	81.961	64.696	80.817	83.866	68.908	.....	90.781	.....	79.419
Hereford calf 564C	75.583	79.394	67.614	80.055	83.806	67.486	77.314	93.059	74.283	78.682
Average for Hereford calves, medium plane	76.075	81.274	68.573	80.588	84.083	68.314	79.084	92.713	.....	79.080
Hereford calf 568B ⁴	79.285 ³	86.842 ³	75.517 ³	83.655 ³	86.621 ³	71.929 ³	77.687 ³	95.910 ³	.....	.....
Hereford calf 567B	76.035	83.016	67.149	81.100	83.955	68.572	81.144	92.964	80.915	79.910
Hereford calf 566B	76.600	82.948	70.886	82.461	84.711	67.402	80.052	92.475	91.921	80.637
Hereford calf 568C	75.319	83.547	68.482	80.118	84.713	65.923	82.914	94.895	92.784	79.076
Average for Hereford calves, low plane	75.985	83.170	68.839	81.226	84.460	67.302	80.454	93.445	.....	79.874
Average for all Hereford calves	76.221	81.930	68.269	80.800	84.217	68.057	80.398	92.875	88.047	79.213

¹Blood sample mixed with some water. ²Blood of this animal with the internal organs. ³Result not included in averages. ⁴Calf underdeveloped and weak.

sult for fat is furnished by the lightest calf, 568B, but this result is practically duplicated by the result from one of the heaviest calves, 565A. By considering averages of each group we see the relation of decreasing fat content with a descending plane of nutrition. Considering the average result of the groups the nitrogen percentage decreases and the ash increases as we pass from the high-plane to the low-plane groups.

Excreta.—The contents of small and large intestines, called excreta, do not show any significant results, but do indicate that the composition may vary widely from average results, as for example in the case of Calf 562C.

TABLE 38.—THE COMPOSITION OF ENTIRE BOVINE FETUS AND CALVES ON MOISTURE AND FAT FREE BASIS

	Nitro- gen %	Ash %	Phos- phorus %
Jersey fetus (185 days) 43X	13.034	13.837	2.205
Jersey fetus (232 days) 13X	10.739	16.981	1.976
Jersey fetus (279 days) 2X	12.198	18.117	3.068
Jersey Calf at birth 11A	12.779	17.707	2.667
Jersey Calf at birth 11B	12.989	18.932	3.258
Jersey Calf at birth 22A, ¹ subnormal	13.393	17.597	3.109
Jersey Calf at birth 85A, ¹ abnormal	12.200	20.398	3.635
Average for Jersey calves 2X, 11A, 11B	12.655	18.252	2.998
Hereford Calf 560B	²	16.949	2.862
Hereford Calf 562B	13.070	17.997	2.881
Hereford Calf 560D	12.836	18.421	4.091
Hereford Calf 562C	12.661	17.531	3.938
Average for Herefords (high plane)	12.856	17.725	3.443
Hereford Calf 565A	12.022	19.592	3.382
Hereford Calf 563A	12.427	18.641	2.958
Hereford Calf 564B	12.577	18.672	3.290
Hereford Calf 565B	12.639	18.851	3.277
Hereford Calf 564C	12.501	18.589	3.965
Average for Herefords (medium plane)	12.433	18.869	3.376
Hereford Calf 568B	12.241	19.552	3.318
Hereford Calf 567B	12.110	20.757	3.472
Hereford Calf 566B	12.113	23.516	4.479
Hereford Calf 568C	11.978	20.625	4.421
Average for Herefords (low plane)	12.111	21.113	3.923
Average for all Herefords	12.431	19.207	3.565

¹Omitted from averages.

²Nitrogen in skeleton not determined.

Kidney Fat.—No relation seems to exist between the composition of the kidney fat (Table 36) and the plane of nutrition of the animal. The results for moisture and fat vary widely even within the same groups. Calf 564B shows a most unusual result of 53.52 per cent moisture and 39.64 per cent fat. This kidney fat was not firm but was flabby and had a slimy feel.

Moisture and Fat-Free Substance.—Consideration of the moisture and fat percentage shows that as the proportion of moisture increases the proportion of fat tends to decrease. In view of the theory that water may displace fat, or fat displace water in the tissues, this relation seems interesting. This constant value of the sum of the moisture and fat percentage appears in the data from calves of all planes of nutrition. Table 37 gives the sum of moisture and fat percentage for all the animals, for each separated part and for the animal as a whole. Each separated part has a certain value toward which the sum of the percentage of moisture

TABLE 39.—COMPOSITION OF THE BLOOD OF THE JERSEY AND HEREFORD CALVES AT BIRTH ON MOISTURE AND FAT FREE BASIS

	Nitro- gen %	Ash %	Phos- phorus %
Jersey Calf 11B	15.887	4.764	0.268
Jersey Calf 22A	15.185	3.436	0.244
Average for Jersey calves	15.536	4.100	0.256
Hereford Calf 560B ¹			
Hereford Calf 562B	15.200	3.612	0.164
Hereford Calf 560D ¹			
Hereford Calf 562C	14.658	4.754	0.159
Average for Herefords (high plane)	14.929	4.183	0.161
Hereford Calf 565A	15.454	2.825	0.208
Hereford Calf 563A	15.359	2.352	0.104
Hereford Calf 564B	15.159	3.326	0.161
Hereford Calf 565B	15.688	3.808	0.194
Hereford Calf 564C	15.287	3.591	0.141
Average for Herefords (medium plane)	15.389	3.180	0.161
Hereford Calf 568B	14.820	3.184	0.197
Hereford Calf 567B	15.061	4.604	0.159
Hereford Calf 566B	14.761	4.011	0.188
Hereford Calf 568C	15.511	4.941	0.146
Average for Herefords (low plane)	15.038	4.185	0.173
Average for all Herefords	15.178	3.728	0.165

¹Blood not obtained as a separate sample.

and fat seems to approximate for all the animals. This would accordingly indicate a corresponding constant value for the moisture and fat-free substances consisting of the nitrogen and mineral bearing part of the tissue. The values for blood in table 37 are the moisture percentages only, there being no ether extract from blood. They do not, therefore, correspond to the values for the other separated parts, which show this constant value for all conditions, more consistently than the blood. If the bodies in the blood, corresponding to the ether soluble bodies in the other tissues, had been estimated and added to the moisture percentages, the results might have been a more constant quantity. One of the interesting facts brought out by this study of the chemical composition concerns Calf 568B. All the results for moisture plus fat vary markedly from that of the other calves. Evidently the development of this calf was distinctly retarded by the low plane of nutrition to which the mother was subjected. As before stated,

TABLE 40.—COMPOSITION OF THE HAIR AND HIDE OF THE JERSEY AND HEREFORD CALVES AT BIRTH ON MOISTURE AND FAT FREE BASIS

	Nitro- gen %	Ash %	Phos- phorus %
Jersey Calf 11B	16.836	2.613	0.225
Jersey Calf 22A	14.533	2.829	0.241
Average for Jersey calves	15.685	2.721	0.233
Hereford Calf 560B	14.939	2.381	0.192
Hereford Calf 562B	16.229	6.730 ¹	0.207
Hereford Calf 560D	16.479	2.873	0.273
Hereford Calf 562C	16.489	3.142	0.209
Average for Herefords (high plane)	16.034	2.799	0.220
Hereford Calf 565A	16.820	5.087	0.225
Hereford Calf 563A	14.322	11.943 ¹	0.226
Hereford Calf 564B	15.481	3.347	0.180
Hereford Calf 565B	15.304	6.311 ¹	0.263
Hereford Calf 564C	16.195	2.822	0.182
Average for Herefords (medium plane)	15.624	3.752	0.215
Hereford Calf 568B	15.652	5.444	0.298
Hereford Calf 567B	15.570	7.984 ¹	0.234
Hereford Calf 566B	15.593	3.651	0.210
Hereford Calf 568C	16.467	2.817	0.190
Average for Herefords (low plane)	15.821	3.971	0.233
Average for all Herefords	15.703	3.507	0.222

¹Omitted from averages. Samples contaminated with some dirt.

this calf was the weakest of all those born in this experiment. Consideration of the data would seem to indicate that this calf had the composition of the fetus at less than full term, but probably farther advanced than 232 days.

Jersey Calf 22A was also a weak calf at birth. The mother was immature, and was growing steadily at the time of the birth of this calf. She had also been in milk for twelve months previously. It is not to be expected under these circumstances that she would have much of a reserve supply. The composition of this calf also shows abnormality in the departure of the moisture plus fat percentage from the values shown by normal animals.

By reducing the percentages of nitrogen, ash and phosphorus to the moisture and fat-free basis as in Tables 38 to 45, the variations in these constituents are magnified as compared with the variations on the fresh basis. No new variations are brought out by these tables which has not already been discussed from Tables 30 to 37.

TABLE 41.—COMPOSITION OF THE COMPOSITE FLESH OF THE JERSEY AND HEREFORD CALVES AT BIRTH ON MOISTURE AND FAT FREE BASIS

	Nitrogen %	Ash %	Phosphorus %
Jersey Calf 11B	15.209	5.088	0.918
Jersey Calf 22A	17.392	4.936	0.947
Average for Jersey calves	16.300	5.012	0.933
Hereford Calf 560B ¹			
Hereford Calf 562B	14.922	5.315	0.837
Hereford Calf 560D	14.488	4.710	0.844
Hereford Calf 562C	13.997	5.296	0.927
Average for Herefords (high plane)	14.469	5.107	0.869
Hereford Calf 565A	14.025	4.832	0.892
Hereford Calf 563A	14.185	5.081	0.791
Hereford Calf 564B	14.575	4.924	0.887
Hereford Calf 565B	14.455	5.422	0.928
Hereford Calf 564C	14.000	5.174	0.923
Average for Herefords (medium plane)	14.248	5.087	0.884
Hereford Calf 568B	13.313	5.249	0.857
Hereford Calf 567B	13.963	5.687	0.915
Hereford Calf 566B	15.622	5.838	0.832
Hereford Calf 568C	13.721	5.105	0.900
Average for Herefords (low plane)	14.155	5.470	0.876
Average for all Herefords	14.272	5.219	0.878

¹Composite flesh not obtained as a separate sample.

Table 3 is presented in order to compare successive calves from the same mother. The live weight at birth is the only figure available for this purpose. The live weights of the first calves of 560, 562, 564, 566, 567, and 568 and of the third calf of No. 560 were obtained by the courtesy of Mr. H. O. Allison formerly of the Department of Animal Husbandry of the University of Missouri. In nearly every case the first and third calf are of about the same weight and more or less heavier than the second calf. Heifer 560 and 566 show an exception—the first calf being lighter than the second.

It does appear probable that the variation between the different calves from the same mother of the high-plane group is not as great as that shown in the medium and low-plane groups. The greatest variation is shown by the calves of No. 568, the second calf weighing about one-half as much as the third calf.

While it appears from this data that the second calf is gener-

TABLE 42.—COMPOSITION OF THE COMPOSITE INTERNAL ORGANS OF THE JERSEY AND HEREFORD CALVES AT BIRTH ON MOISTURE AND FAT FREE BASIS

	Nitro- gen %	Ash %	Phos- phorus %
Jersey Calf 11B	14.868	6.444	1.059
Jersey Calf 22A	13.595	6.308	1.399
Average for Jersey calves	14.231	6.376	1.229
Hereford Calf 560B ¹	13.398	7.618	1.260
Hereford Calf 562B	14.731	7.143	1.153
Hereford Calf 560D	13.237	7.021	1.353
Average for Herefords (high plane)	13.789	7.261	1.255
Hereford Calf 565A	13.297	6.985	1.359
Hereford Calf 563A	13.235	7.135	1.124
Hereford Calf 564B	13.207	6.520	1.270
Hereford Calf 565B	13.561	7.183	1.382
Hereford Calf 564C	13.486	6.916	1.346
Average for Herefords (medium plane)	13.357	6.948	1.296
Hereford Calf 568B	13.962	7.108	1.225
Hereford Calf 567B	13.586	7.703	1.433
Hereford Calf 566B	13.807	6.933	1.393
Hereford Calf 568C	12.815	6.810	1.295
Average for Herefords (low plane)	13.542	7.138	1.336
Average for all Herefords	13.527	7.090	1.299

¹Internal Organs not obtained as a separate sample.

any the smaller of the first three calves, there are enough exceptions to forbid calling this a rule.

SUMMARIZED DISCUSSION OF THE INDIVIDUAL CALVES

THE JERSEY CALVES

Jersey Calf 22A five days old does not show any conclusive difference in composition compared with the Jersey calves 11A and 11B obtained at birth. All of these may be considered normal calves. The first calf, 11A, was the heaviest and in conformity with the prevailing tendency shows less moisture and higher fat percentage in the entire animal than does the lighter calf, 11B. Jersey Calf 22A seems to show from the chemical analyses many indications of being a poorly nourished calf. The proportion of skeleton and internal organs to live weight is higher than for the normal Jersey calf 11B. The hide of this calf was also lighter in

TABLE 43.—COMPOSITION OF THE COMPOSITE SKELETON OF THE JERSEY AND HEREFORD CALVES AT BIRTH ON MOISTURE AND FAT FREE BASIS

	Nitro- gen %	Ash %	Phos- phorus %
Jersey Calf 11B	8.825	42.777	7.492
Jersey Calf 22A	9.617	36.729	6.473
Average for Jersey calves	9.221	39.753	6.983
Hereford Calf 560B .....	.....¹	40.583	6.974
Hereford Calf 562B	9.374	41.428	7.160
Hereford Calf 560D	9.331	41.172	9.630
Hereford Calf 562C	9.642	38.212	9.204
Average for Herefords (high plane)	9.449	40.349	8.242
Hereford Calf 565A	7.993	42.467	7.570
Hereford Calf 563A	9.462	39.646	7.222
Hereford Calf 564B	9.192	42.130	7.651
Hereford Calf 565B	9.018	41.959	7.764
Hereford Calf 564C	9.277	41.658	9.347
Average for Herefords (medium plane)	8.968	41.572	7.911
Hereford Calf 568B	9.746	38.691	6.900
Hereford Calf 567B	8.813	42.443	7.646
Hereford Calf 566B	7.982	47.453	9.451
Hereford Calf 568C	8.806	42.905	9.616
Average for Herefords (low plane)	8.837	42.873	8.403
Average for all Herefords	9.053	41.596	8.164

¹Nitrogen in skeleton not determined.

proportion to the live weight than any other calf handled in the investigation. The amount of moisture found, however, is not as high as we ought to expect from other indications. The percentage of water is high in the blood and internal organs, but about normal in the hair and hide, flesh, and skeleton. The fat in the animal, however, is very low or about one-half as much in the dry substance as in other calves of about the same plane of nutrition. The fat appears to be deficient in all parts of the animal.

The low mineral calf, 85A, shows in the percentage of constituents but one indication of low nutrition or under development. This is the high percentage of water. The effect of low mineral diet fed to the mother resulted in the calf being defective, but the percentage of mineral found in the calf is about normal.

TABLE 44.—COMPOSITION OF THE EXCRETA OF THE JERSEY AND HEREFORD CALVES AT BIRTH ON MOISTURE AND FAT FREE BASIS

	Nitro- gen %	Ash %	Phos- phorus %
Jersey Calf 11B	9.134	4.687	0.082
Jersey Calf 22A ¹ .....	.....	.....	.....
Average for Jersey calves .....	.....	.....	.....
Hereford Calf 560B ¹ .....	.....	.....	.....
Hereford Calf 562B	8.089	5.514	0.125
Hereford Calf 560D	9.389	5.115	0.563
Hereford Calf 562C	8.364	10.845	0.358
Average for Herefords (high plane)	8.614	7.158	0.349
Hereford Calf 565A	8.169	5.160	0.095
Hereford Calf 563A	8.338	5.579	0.161
Hereford Calf 564B	10.688	4.726	0.296
Hereford Calf 565B ¹ .....	.....	.....	.....
Hereford Calf 564C	7.939	5.263	0.299
Average for Herefords (medium plane)	8.783	5.182	0.213
Hereford Calf 568B	8.362	4.571	0.179
Hereford Calf 567B	8.586	5.436	0.100
Hereford Calf 566B	8.301	5.303	0.606
Hereford Calf 568C	8.112	6.011	0.451
Average for Herefords (low plane)	8.340	5.330	0.334
Average for all Herefords	8.576	5.775	0.294

¹Excreta not analyzed.

THE HERFORD CALVES

The live weight of the Hereford calves is not necessarily determined by the plane of nutrition of the mother. Each group shows all degrees of variation in live weight. Of the five heaviest calves, 562B and 562C are from the high plane, 565A and 563A are from the medium plane, and 566B from the low plane. The four calves of the high-plane group all show a well-nourished condition in having a high percentage of flesh to live weight of animal and relatively high percentage of fat in the entire animal.

The data on Calf 560B cannot be considered altogether reliable. The weights of the penis, testicles, and diaphragm are missing, yet the sum of all the parts as given is greater than the live weight of the calf before slaughter. The data marked with the asterisk in Table 6 may be considered unreliable, especially the

TABLE 45.—COMPOSITION OF THE KIDNEY FAT OF THE JERSEY AND HERFORD CALVES AT BIRTH ON MOISTURE AND FAT FREE BASIS

	Nitro- gen %	Ash %	Phos- phorus %
Jersey Calf 11B	14.932	.....¹	.....¹
Jersey Calf 22A	14.607	.....¹	.....¹
Average for Jersey calves	14.769	.....	.....
Hereford Calf 560B ¹ .....	.....	.....	.....
Hereford Calf 562B	14.509	8.107	1.009
Hereford Calf 560D	16.131	7.467	1.345
Hereford Calf 562C	13.072	6.791	1.106
Average for Herefords (high plane)	14.571	7.455	1.153
Hereford Calf 565A ¹ .....	.....	.....	.....
Hereford Calf 563A	14.169	6.898	1.233
Hereford Calf 564B	17.264	9.020	1.333
Hereford Calf 565B	14.774	6.562	1.313
Hereford Calf 564C	14.940	8.630	1.268
Average for Herefords (medium plane)	15.287	7.778	1.287
Hereford Calf 568B	19.823	9.458	2.229
Hereford Calf 567B	13.288	7.688	1.264
Hereford Calf 566B	12.957	8.000	1.262
Hereford Calf 568C	10.832	7.581	1.684
Average for Herefords (low plane)	14.225	8.182	1.610
Average for all Herefords	14.705	7.836	1.368

¹Not determined.

²Kidney Fat not analyzed.

data on the composite flesh. The rest of the data may be considered dependable. The experimenter who handled this calf was new to the work and did not record his data under the eye of the more experienced chemists, and it was not checked carefully as he proceeded. It is for the sake of completeness that these data are included with the others.

Of the other three high-plane calves all stand on about a level as regards proportionate amount of flesh and fat. Calf 562C shows a rather lighter hide, and heavier skeleton, than the other two calves. The high value for the internal organs of Calf 560D is due to the fact that the blood of the animal was weighed with these parts, since the animal was not bled.

Hereford Calf 563A is the heaviest calf shown in this report. This calf shows the highest proportion of hair and hide to live weight of all the Hereford calves. In flesh, organs, and skeleton, the proportion is much the same as for the other heavy calves. The chemical composition shows that this calf leads slightly in condition of fatness as compared with other calves in the medium-fed group, altho intermediate in fatness with the other four heavy calves.

Hereford Calf 564B is the lightest of the medium-fed calves and the results in many cases seem erratic and unexplainable as compared with the others in the group. The blood and the internal organs are high in weight as compared to the live weight, while the weight of flesh is proportionately rather low. The stomach and intestines of this calf weigh much more in proportion to the live weight than do the same parts of the other Hereford calves. The great length of the small intestines is one of the striking facts in the results for this calf. The most erratic result is the composition of the kidney fat which contained about 14 per cent less fat and about 16 per cent more water than the kidney fat nearest to it in composition.

All things considered, Calf 565B appears to be about the best nourished of the medium-plane group. The percentage of flesh to live weight is higher than the average value for the group. The analysis of the parts shows a high percentage of fat content especially in the flesh and skeleton. Calf 565A from the same mother is also well nourished, showing a high percentage of flesh but not as much fat as Calf 565B. Calf 564C from the same mother as 564B shows, like the latter, the great length and therefore capacity of intestinal tract. This calf was better nourished than calf 564B as is shown by the live weight and the percentage

of flesh. The flesh and skeleton, however, did not contain as much fat proportionately as Calf 565B.

All calves of the low-plane group show a high proportion of bone to live weight of animal.

Calf 568B is the lightest of all the Hereford calves and was quite weak at birth. The blood, hair and hide, internal organs, and skeleton are high in proportion to the live weight while the flesh is proportionally low. The per cent of moisture in the entire animal is high, which is the usual result found with under-developed animals. This high per cent of moisture is found to occur in every part of the animal. As has already been pointed out, the sum of the moisture plus fat percentage also indicates the normal composition of a calf some weeks before birth rather than of a calf at birth.

Hereford Calf 567B from a low plane of feeding gives about the same proportion of blood, hair and hide, flesh, and internal organs as was shown by the medium-fed calves. The effect of the low plane of feeding on this calf is seen, however, in the high proportional weight of skeleton to live weight; also in the low percentage of fat in the composition of the animal taken as a whole.

Hereford Calf 566B tho also from the low-plane group is one of the heaviest calves obtained in the experiment. His thriftiness is also indicated by his high proportion of flesh to his live weight. He does not show, however, the presence of much fat in any part. He was a large-boned calf as is evident by the high proportion of skeleton to live weight and the high percentage of mineral matter in the animal taken as a whole.

GENERAL SUMMARY

DIFFERENCES DUE TO BREED

Jersey and Hereford calves at birth show some differences in weights of parts into which the animals were divided for analysis. The weights of the stomachs and intestines and consequently of the internal organs as a whole, of the Jersey calves, are a higher percentage of the live weight of the animal than in the case of the Hereford calves. The weight of the hair and hide and possibly of the skeleton of the Hereford calves is higher in proportion to the live weight than in the case of the Jersey calves. There is no apparent difference in chemical composition due to breed.

DIFFERENCES DUE TO PLANES OF FEEDING

This could be studied only with the Hereford calves. The thriftiness of the calves born in this experiment seem to depend upon the condition of the mother, and the condition of the mother may or may not have been affected by her feeding when the calf was produced. Calves of full weight at birth were produced from all three groups representing the three planes of feeding. From the high plane of feeding, there were three calves of full live weight and one of medium weight; from the medium plane of feeding were obtained three calves of full live weight and two of medium weight; from the low plane, one calf of full live weight, two of medium weight and one of low weight. The average of these results show that the live weight of calves at birth from the high and medium planes of nutrition were practically the same, the high plane being slightly heavier. The low-plane calves average appreciably lower than the medium-plan calves.

As regards the separated parts, the proportion of flesh decreases and the proportion of skeleton and internal organs increases as we pass from the high plane to the low plane of nutrition.

Considering the average composition of the calves, the proportion of fat and nitrogen decreases and the proportion of moisture, ash, and phosphorus increases as we pass from the high plane to the low plane of nutrition. Most of the fat of the new-born calf is found with the internal organs; the flesh and the skeleton contain some also but in small proportions. The sum of the percentages of moisture and fat, and consequently the percentage of moisture and fat-free substance, tends to a constant value, in new-born calves of normal thrift, regardless of the plane of feeding of the mother.

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